STUDY OF DISTRIBUTION PATTERN AND ECOLOGICAL ANALYSIS OF MAJOR FOREST TYPES OF MEGHALAYA

ABSTRACT

By

Om Prakash Tripathi

THESIS SUBMITTED IN FULFILMENT OF THE DEGREE OF
DOCTOR OF PHILOSOPHY IN BOTANY

DEPARTMENT OF BOTANY
OF
NORTH-EASTERN HILL UNIVERSITY
SHILLONG - 793 022, INDIA

2002

ABSTRACT

The present study was conducted in three major forest types *viz.*, subtropical evergreen, subtropical semi-evergreen and subtropical pine forests of Meghalaya to study their distribution pattern, floristic composition, community structure, tree population structure and regeneration of dominant tree species. Their distribution pattern was studied using satellite Remote Sensing data and Geographical Information Systems, while community studies were carried out in two to three representative stands of each of the three forest types distributed in different parts of the state during March 2000 to February 2002.

As per the Report of Forest Survey of India (1999), total forest cover of the state is about 69.7% of the total geographical area. The subtropical evergreen forests account for 17.1%, subtropical semi-evergreen forests 30.7% and subtropical pine forests 10.9% of the total forested area of the state. Together they cover about 59% (*ca.* 41% of the total geographical area) of the total forest area of the state.

The climate of the state is strongly seasonal with 7-8 month-long rainy season and 4-5 months of relatively dry winter; summer is brief and mild. On account of wide variation in the annual rainfall from 1600 mm to 11,000 mm, a distinct climatic gradient from moist to perhumid condition exists in the state. The mean maximum temperature ranges between 15.1 ^{0}C and 31.7 ^{0}C and mean minimum temperature between 7.9 ^{0}C and 19 ^{0}C. The soils supporting

these forests are lateritic, acidic, low in TKN and available P and fairly high in SOM. The evergreen and semi-evergreen broad-leaved forests are found between 1000 m and 2000 m asl and the pine forests are distributed between 800 m and 2000 m asl. Since all three types of forests are distributed within the same altitudinal range, having similar rainfall and temperature regimes, their distribution at specific sites in different parts of the state appears to be related to the site conditions, particularly the soil moisture level and intensity of disturbance.

All the three forests are highly fragmented. About 60 to 90% of the forest patches are less than (≤) 10 sq. km area. Only 1 to 5% patches have an area of ≥ 100 sq. km. The pine forest is more fragmented than the broad-leaved forests.

In the broad-leaved forests, trees were distributed in three distinct strata namely, canopy (>20 m), sub-canopy (10-20 m) and treelet (2-10 m) layers. The average height of the canopy trees was greater in the semi-evergreen forest than the other two types. The pine forest had only two distinct strata, *i.e.* canopy and sub-canopy layers. The canopy in evergreen forest was composed of *Castanopsis tribuloides*, *Engelhardtia spicata*, *Dysoxylum gobara,* while *Vitex altissima*, *Schima wallichii*, *Echinocarpus murex*, *Dysoxylum binectariferum* and *Syzygium tetragonum* were conspicuous canopy trees in the semi-evergreen forest. In pine forest the canopy was made of either pure pine or pine mixed with some broad-leaved trees such as *Rhododendron arboreum* and *Schima wallichii.* There were 76-93 tree species (>15cm cbh) in the evergreen, 77-102 species in the semi-evergreen and 9-26 species in the pine forest. In the broad-leaved forests majority (79-88%) of the tree species was present in the sub-canopy and treelet strata, while in the pine forest the treelet layer (shrubs and tree saplings) had 77-81% of the woody species in the community. Lianas were absent in the pine forest.

The proportion of phanerophytes was 53 to 54% in the evergreen and semi-evergreen forests, which decreased to 33% in the pine forest, however, the proportion of therophytes was markedly higher (32%) in this forest compared to the other two forest types.

Whittaker's α-diversity (179-211) was highest in the subtropical semi-evergreen forest followed by evergreen (159-176) and pine (54-134) forests.

The tree species richness or species density per 100 m^2 was also high (3-27 species) in the semi-evergreen followed by evergreen (5-24 species) and pine forests, which had only 1-2 species. Species richness, species diversity and evenness indices were high in semi-evergreen and evergreen forests than the pine forest. Dominance index showed a reverse trend.

The evergreen and semi-evergreen forests were more heterogeneous and patchy in nature than the pine forest. *Saprosma ternatum*, *Syzygium cuminii* and *Aporusa oblonga* in evergreen, *Ficus racemosa*, *Daphniphyllum himalayense* and *Glochidion assamica* in semi-evergreen and *Pinus kesiya* in pine forests were the most frequent tree species.

Castanopsis kurzii, *Ficus elastica* (canopy species) and *Rhus javanica* (treelet layer) were dominant in the evergreen forests, *Dysoxylum* *binectariferum, Syzygium tetragonum* (canopy species) and *Aporusa oblonga* (sub-canopy layer) in the semi-evergreen forests and *Pinus kesiya* (canopy species), *Myrica esculenta*, and *Quercus glauca* (sub-canopy) were considered dominant in the pine forests on the basis of importance values. On the basis of family importance value Lauraceae, Rubiaceae and Euphorbiaceae were dominant in the subtropical evergreen and subtropical semi-evergreen forests. Pinaceae was the dominant family in the subtropical pine forest.

The tree stand density (stems per ha) was 834 - 1723 in the evergreen forest, 838 - 1063 in the semi-evergreen forests and 810 - 1050 in the pine forest. Their basal cover (m^2 ha^{-1}) ranged between 27 and 38.8, 25 and 49.5, and 28.9 and 37.4 in the evergreen, semi-evergreen and pine forests, respectively.

The dominance-distribution curves (log normal) of tree species showed high equitability and low dominance in evergreen and semi-evergreen forest communities and high dominance and low equitability (broken stick and geometric series model) in the pine forest.

The girth-class distribution pattern in the dominant species *viz.*, *Castanopsis indica*, *C. tribuloides*, *Callicarpa vestita* and *Symplocos spicata* in the evergreen forest, *Randia wallichii*, *Ficus racemosa*, *Helicia nilagirica*, and *Antidesma acidum* in the semi-evergreen forest and *Pinus kesiya* in stand P-I of the pine forest showed upright pyramidal population structure with large number of young (<15 cm cbh) individuals in their populations.

Pyramids of numbers of seedlings, saplings and adult trees in all the three-forest types were upright indicating good regeneration. However, a close examination of the population behaviour of the ten dominant tree species in each of the three forest types revealed wide variation in their regeneration behaviour. Regeneration was good in some species (*Castanopsis indica*, *Engelhardtia spicata, Helicia nilagirica* and *Callicarpa vestita*), poor in others (*Bridelia retusa, Persea duthiei* and *Rhododendron arboreum*), and in some species (*Ficus elastica* and *Saprosma ternatum*) no regeneration was observed. Poor regeneration could be due to several reasons, for example, the nature of species, non-availability of seeds, poor seedling establishment due to resource competition and alteration in regeneration niches due to disturbance.

Conclusions

All the three forest types are found inter-mixed at higher elevations of Meghalaya under similar climatic condition. However, the evergreen forest is found mainly at more humid and inaccessible least disturbed sites and, therefore, it is less fragmented. In this forest, the tree species richness and height of the canopy trees is lower than the semi-evergreen forest.

Though all the three forests fragmented, the pine forests found on nutrient-poor and relatively dry soil, are more fragmented and are poor in tree species richness than the other two types. In spite of the fragmentation and disturbance, regeneration of the dominant tree species in the evergreen and semi-evergreen forest is satisfactory. In pine forest regeneration of *Pinus kesiya* and *Schima wallichii* is better at warmer and moderately disturbed sites.

STUDY OF DISTRIBUTION PATTERN AND ECOLOGICAL ANALYSIS OF MAJOR FOREST TYPES OF MEGHALAYA

By

Om Prakash Tripathi

THESIS SUBMITTED IN FULFILMENT OF THE DEGREE OF
DOCTOR OF PHILOSOPHY IN BOTANY

DEPARTMENT OF BOTANY
OF
NORTH-EASTERN HILL UNIVERSITY
SHILLONG - 793 022, INDIA
2002

THE NORTH-EASTERN HILL UNIVERSITY

DECEMBER, 2002

DECLARATION

I, Om Prakash Tripathi, hereby declare that the subject matter of this thesis entitled "**Study of distribution pattern and ecological analysis of major forest types of Meghalaya**" is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

This is being submitted to the North-Eastern Hill University, Shillong for the award of the degree of Doctor of Philosophy in Botany.

Tripathi 16/12/02
(Om Prakash Tripathi)

18/12/02
(Head of the Department)

16/12/02
(Joint Supervisor)

16/12/02
(Supervisor)

Head
Department of Botany
School of Life Sciences
N. E. H. U.
Shillong-793022

ACKNOWLEDGEMENTS

I am extremely grateful and deeply indebted to my Supervisor, Professor H.N. Pandey, Department of Botany, North-Eastern Hill University, Shillong, for his valuable guidance, constant encouragement and untiring help throughout the course of this study.

I express my deep sense of gratitude to my Joint Supervisor Professor R.S. Tripathi, FNA, Department of Botany, North-Eastern Hill University, Shillong, who has been a constant source of inspiration to me. I sincerely thank him for his inspiring guidance, encouragement, generosity, keen interest and constructive criticisms which enabled me to successfully complete this study.

I am grateful to Professor A.K. Misra, Head, Department of Botany, North-Eastern Hill University, Shillong and Professor H.N. Pandey, the former Head, Department of Botany, North-Eastern Hill University, Shillong for extending necessary facilities. I also thank Dr. S.K. Barik, Dr. Uma Shankar, Dr. N. K. Chrungoo and Dr. Y. Kumar, the faculty members of this Department, for their support and help.

I am grateful to Professor P.S. Roy, Dean, Indian Institute of Remote Sensing, Dehra Dun, and Project Director, DOS-DBT Project on "Biodiversity Characterisation at Landscape level using Satellite Remote Sensing data and GIS" for his valuable suggestions and help and for extending facilities at his Institute to learn the use of Remote Sensing techniques and GIS. I extend my gratitude to Professor S.P.S. Kushwaha, Head, Forestry and Ecology Division, IIRS, Dehra Dun, for his valuable advice, help and unstinted support. I also thank Dr. M.C. Porwal (Scientist F, IIRS) and Dr. M.L. Khan, Department of Forestry, NERIST, Itanagar, Arunachal Pradesh, for constructive suggestions.

I would like to thank Professor A.P. Das (Department of Botany, North-Bengal University), Dr. K.P. Singh (the then Joint Director at BSI, North-Eastern

Circle, Shillong) and Dr. P.B. Gurung of the Department of Botany, NEHU, Shillong for their help with plant identification.

I am thankful to Shankar Das of BSI, Mr. Rameshwar Rai (Field Assistant), Mr. H.R. Choudhury (Artist), Mr. P.B. Das (Store-Keeper), Mr. K. Sholang (Photographer) and Mr. B.D. Rathore (STA) of the Department of Botany for their help in various ways.

I sincerely thank Dr. B.P. Mishra for his suggestions, help and cooperation throughout the study period. I am also thankful to other scholars of the Ecology Research Group *viz.*, Dr. Babu John, Dr. Subhasis Das Gupta, Dr. S. A. Jamir, Mr. Nripemo Odyuo, Mr. Krishna Upadhaya, Mr. Pynsakhiat Law, Mr. Kanhaia Lal Choudhary, Ms. Swapna Prabhu, Ms. Valhuraii Ralte, Ms. Shairi Nongbri and Ms Bishwarupa Ghosh for their help and cooperation.

Thanks are also due to my friends Mr. Girija Shankar Chaubey, Mr. Kiranmay Sharma, Mr. Tomba Singh, Mr. Jagmohan Singh Tomar, Mr. Arumugan Murugan, Mr. Sarat Changmai, Mr. Niranjan Das and Mr. V.A. Sivadashan who helped me in various ways.

I express my grateful thanks to my father Shri. Raj Nath Tripathi, my mother, and all the family members for their inspiration and support. I thank my wife Mrs. Anju Tripathi for the moral support and for her patience.

The financial support received from the Indian Institute of Remote Sensing, Dehra Dun, Department of Space, Government of India out of a DOS-DBT funded research project entitled "Biodiversity Characterization at Landscape level using Satellite Remote Sensing data and GIS" (Sanction letter No. IIRS/FED/73 dated August 30, 1999) is gratefully acknowledged.

Tripathi

Date: 16/12/2002 (Om Prakash Tripathi)

CONTENTS

CHAPTER I

INTRODUCTION

Forests cover an area of 3454 million ha (26.6%) of land surface (FAO 1997) on the Earth. Nearly 57% of the forest lay in developing countries, which for the most part are tropical and make up 58.9% of the total land area. They occur in three major climatic zones *viz.*, tropical, temperate and alpine zones of the earth. The tropical forests form almost a continuous belt along the equator. The temperate forests occur up to about 60^0 N and S latitudes (Evans 2001), while the boreal forest extend as a continuous vegetation belt of varying width across Eurasia and North America reaching up to 72^0 30' N in Siberia (Archibold 1995). Deciduous forests are mostly confined in tropics, subtropics and lower latitudes of the temperate lands due to seasonality of cold and rainy periods.

Forests are renewable resources that contribute substantially to the social and economic development of the people. They preserve seed stock of plants and support large number of animals and microbes. Besides, they are effective sink of CO_2, which is steadily increasing at global level and contribute to the normal functioning of the biosphere. However, due to increasing pressure of human population and consumptive life style, the precious forest resources have been dwindling over the years. Forest is a national asset, and needs to be protected for the well being of the people. A thorough understanding of their distribution, community structure and functioning is a prerequisite for evolving strategies for their scientific management and conservation.

Forests have distinctive characters that make them different from other terrestrial communities on the Earth. Forests have been classified primarily on the basis of physiognomy, floristic composition, community structure, and dynamics, physical environment and history.

An updated knowledge of the forest cover and land utilization pattern is an essential for a better scientific management of forest resources. Forest cover has largely stabilized in most industrialized countries, but deforestation continues in many developing countries. Between 1990 and 1995, the area of natural forests in developing countries decreased by an estimated 13.7 million ha per year, although this rate of loss appears to be slightly less than during the period 1980-1990. Utilization of forest resources beyond their productive potential has resulted in their quantitative and qualitative depletion. Deforestation also leads to depletion of soil nutrients, soil erosion and changes in local and global climate.

The forest cover of India is about 76.52 million ha. In terms of legal status, reserved, protected and unclassed forests constitute about 54.44%, 29.18% and 16.38%, respectively of the total recorded forest area. After independence, a large portion of forested area was diverted at an annual rate of 0.15 million ha to various non-forestry activities. After the enactment of Forest Conservation Act (Forest Conservation Act 1980), the forest diversions have been considerably reduced and present rate of diversion is 16000 ha per year (FSI 1997).

Though the forest cover of India, as per Forest Survey of India Report (1999), is 19.2% of the total geographical area of which probably less than 1% of the total land area is covered by primary forest (Mani 1974). The forest cover of the northeast India including Sikkim is about 62.7% (1,64,359 square km) of the total geographical area (2,62,057 square km) of the region and about 5% of the total forest cover of the India, while this region covers only 7.97% area of the total geographical area of India (FSI 1999).

India is among the top twelve megadiversity countries in the world in terms of biodiversity. As a large tropical country, India ranks high in terms of Asian species richness. Dinerstein and Wikramanayake (1993) have reported about 15,000 plant species from India, which supports about 5-8% of the world's known flowering plant and animal species, a significant proportion of which is endemic (Gadgil and Meher-Homji 1986). Important regions of plant diversity in India are the Western Ghats, northeastern India, and Andman and Nicobar Islands (Nayar 1996). Biogeographers have recognised northeastern region of India as one of the most florally and faunally diverse regions since long time (Mani 1974).

Northeast India, an extension of the eastern Himalayan complex, is a "hot spot" of biodiversity. About 50 % species of the Indian flora is confined to this region (Rao and Hajra 1986). The varied physiography, soil and climatic conditions of the region are responsible for the luxuriant growth of various types of forest. The landscape of the Meghalaya state lies in the northeastern Indian biogeographic zone (Rodger and Panwar 1988), and lays at the junction of Paleoarctic, Indo-Malayan and Indo-chienese biogeographic realm. The forest flora of the state is remarkable in two ways; firstly, it shows high degree of endemism and secondly, it consists of a number of taxonomic elements of neighbouring countries (Balakrishnan 1981-1983).

Kanjilal *et al.* (1934-40), Champion and Seth (1968), Balakrishnan (1981-83), Haridasan and Rao (1985-87), Rao and Hajara (1986), Chauhan and Singh (1992) and Tomar (1998) have classified the natural vegetation of Meghalaya. They have divided the vegetation into tropical evergreen forest, tropical semi-evergreen forest, subtropical broad-leaved hill forest, tropical moist deciduous forest, temperate forest, subtropical pine forest and grassland and savanna based on site condition and floristic composition. Major forests *viz.*, subtropical evergreen forest (11.9%), subtropical semi-evergreen forest (21.4%), and subtropical pine forest (7.6%) cover 40.9% of the total geographical area of the state.

The subtropical evergreen and semi-evergreen forests of Meghalaya cover large areas. Evergreen forest patches are confined to remote areas with complex terrain and are less influenced by humans. They include sacred groves and reserve forests. Subtropical pine forests of the state are secondary in nature, where further succession has been arrested due to complex interaction of biotic and edaphic factors. These forests are mostly confined to higher reaches of Khasi and Jaintia hills and are highly fragmented. The impact of shifting cultivation is less in evergreen forests and greater in semi-evergreen forests as the former are not easily accessible while the latter are confined to less complex terrain.

During 1980-81, about 70% of the total geographical area of the state was under the forest cover; 18% area was covered with dense forest (canopy cover > 40%) and 52% with open forest (canopy cover 10-40%) (FSI 1995). Recent mapping of forest vegetation shows a 2% decline in the forest cover of the state (FSI 1997), and the major cause of this decline is shifting cultivation, which is still continuing unabated.

Recent developments in Remote Sensing technology and Geographical Information System allow us to address the problem of deforestation and biodiversity conservation at landscape level. The landscape approach include analyses of landcover, landuse change, estimation of deforestation rates and rates of forest fragmentation, modelling of deforestation, analysis of the consequences of landcover and landuse change on climate and distribution of biodiversity. It is also useful in analysis of the effectiveness of the protected area network in conserving biodiversity and conservation planning (Menon and Bawa 1997).

The landscape ecology approach departs from traditional approaches by focussing on the structure, function, and spatial patterns on landscape elements and on changes in the landscape mosaic through time. Furthermore, this approach has numerous applications in conservation planning because the total area, patchiness, and connectivity of ecosystems and habitats, and their representation in the protected area network are all important for biodiversity conservation. Although Remote Sensing technology is readily available in India, but its use in landscape ecology and biodiversity conservation has been very limited. Spatial data from varieties of sources such as topographic maps, thematic maps, satellite imagery, and field studies can be incorporated into a GIS to examine the spatial and temporal patterns of landcover and landuse changes (FAO 1990, Liu *et al.* 1992, Menon and Bawa 1997).

The fate of biodiversity ultimately depends upon the existence and integrity of protected areas. Information about landscape changes can be integrated with data on spatial distribution of biodiversity and protected areas in order to devise effective conservation planning strategies. The last few years have witnessed an explosive growth in application of GIS and RS technologies to study changes in the landscape.

These technologies have been used in micro-level planning and sustainable forestry (Lakshmi and Dutta 1996), meso-scale analysis of forest (Lele 1998), estimation of forest resources (Vijaykumaran and Menon 1998), forest type classification and spatial dynamics of vegetation mapping and monitoring of land cover dynamics (Tomar 1998).

Satellite remote sensing has been used to map and classify landuse and vegetation cover in various remote and inaccessible areas (Frank 1988, Lal *et al.* 1991, Millette *et al.* 1995). Vegetation mapping, a prime function of environmental remote sensing and often an important management priority, can also prove difficult in mountainous regions due to a lack of unique spectral reflectance/absorbance patterns across variations in cover types (Frank 1988). Digital terrain data, primarily elevation and aspects, has been used in combination with spectral data to classify vegetation in mountain environments (Frank and Thorn 1985, Frank 1988, Giles *et al.* 1994).

Fragmentation of the forests has serious ecological and environmental implications. Forest destruction and fragmentation increase vulnerability of the forest community to disturbances (Chen *et al.* 1992, Robinson *et al.* 1992, Matlack 1994) and lead to micro-environmental changes that drastically influence the forest under-storey (Kapos *et al.* 1995). After fragmentation, the remaining forest patches are surrounded by different vegetation/land-uses and an abrupt edge is created between forest and the surrounding vegetation (Saunders *et al.* 1991). These edges influence abundance and distribution of organisms across the landscape (Mills 1995, Murcia 1995).

Fragmentation is also considered as one of the major threats to biodiversity. It often causes depletion of biodiversity (Kareiva 1994), eliminates resource entirely (changing landscape composition) or rearranges resources into new configurations. In the Indo-Malayan realm of which the northeast India is a part, degradation activities have altered the natural landscape to a great extent, resulting in mosaics of man-made and natural landscape with poor species composition.

The landscape of the state of Meghalaya has undergone heavy transformation in recent times. The major factors responsible for the change are developmental activities, shifting cultivation (Jhum), urbanisation, commissioning of hydroelectric projects, mining and extraction of forest products. All these activities are responsible for wide-spread fragmentation of natural forests as is evident from the preponderance of small patches of both tropical and subtropical forests in fragmentation map of the state based on the IRS IB LISS II, 1995 imagery (Tomar 1998).

A number of earlier workers (Singh 1980, Khan *et al.* 1987, Barik 1992, Rao 1992, Arunachalam 1996, Tripathi *et al.* 1996, John 1998, Maithani *et al.* 1998, Tomar 1998) have studied different aspects of ecology of forest ecosystem of Meghalaya. However, a comprehensive macro-level study on the distribution pattern of the major forest types of the state and their ecological analyses are yet to be attempted. The present study was carried out with an aim to fill this gap using Remote Sensing technique and Geographical Information System.

The major objectives of the study were:

- To study the distribution pattern and area covered by three major forest types of the state of Meghalaya *viz.*, subtropical evergreen, subtropical semi-evergreen and subtropical pine forests.
- To assess tree species richness of the above forest types.
- To study the vegetation and soil characteristics of the above forest types.
- To study the population structure and regeneration of important tree species of the above major forest types.

The present thesis based on an extensive field study and analysis of IRS ID LISS III imagery aims at fulfilling the above objectives. It comprises the following chapters.

Chapter I. Introduction

Chapter II. Review of literature

Chapter III. Study sites and Methodology

Chapter IV. Forest types of Meghalaya: their distribution, climate and soil

Chapter V. Community structure of subtropical evergreen forest

Chapter VI. Community structure of subtropical semi-evergreen forest

Chapter VII. Community structure of subtropical pine forest

Chapter VIII. General Discussion

CHAPTER II

Study sites and Methodology

The state of Meghalaya lies between latitude 25^0 02' and 26^0 07' N, and longitude 89^0 49' and 92^0 50' E with an area of 22, 429 square km. Being a part of the northeastern Indian bio-geographic zone (Rodgeres and Panwar 1988), it constitutes the junction meeting place of paleo-arctic, Indo-Malayan and Indo-Chinese bio-geographic realms. The topography of the state is variable and the elevation ranges from 60 m to 2040 m asl. The state has high concentration of plant species and harbours about 3128 (21%) including 1237 endemic flowering plants in just 0.7% of the country's land area (Khan *et al.* 1997).

Geology

Meghalaya represents the remnant of the ancient plateau of Pre-Cambrian Indian peninsula and forms a prominent geomorphic unit stretching across the Garo, Khasi and Jaintia hills in east-west direction. The central and northern part of Meghalaya plateau is made essentially of highly metamorphosed crystalline rocks of Pre-Cambrian origin, which are often referred to as "Archaean Gnessic Complex" (Anon 1974, Murthy *et al.* 1976). It is made up of gneisses (biotic gneiss, biotite granulite, quartz-sillimanite gneiss, cordierite, garnet and chondrodite) and Schistose (mica schist, quartz-sillimanite schist and metabasite) members of varying composition.

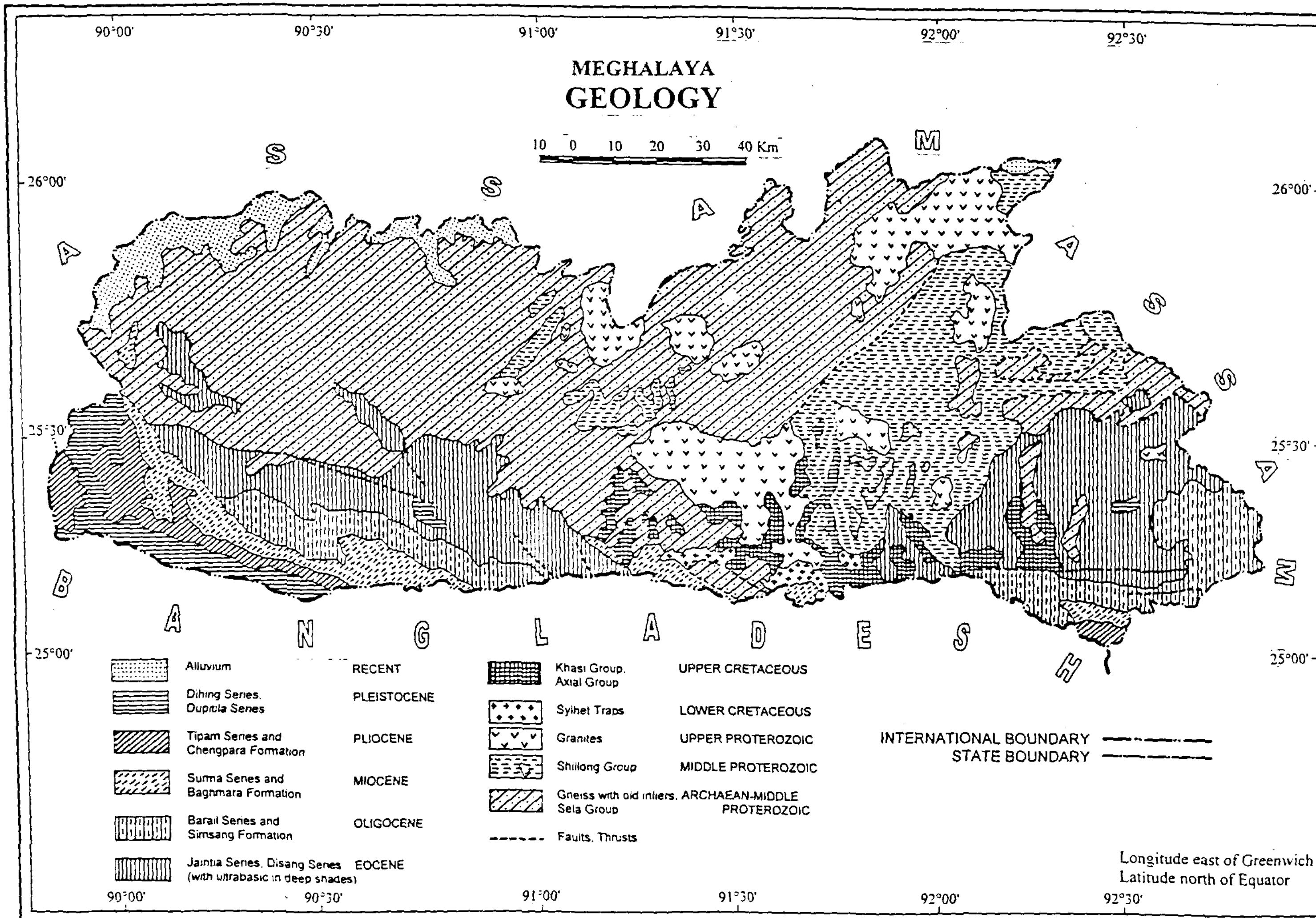
The Meghalaya-Karbi plateau are linked with Chotanagpur plateau with an under grouped extension below the Raja Rajshahi-Rongpur gap (Rajmahal-Garo Gap or Malda Gap) (Rai 1986). The massif is a geomorphological arch bounded on all sides by faults (Majumdar 1986). The southern and northern boundaries are marked by the Dauki fault and Brahamputra lineament, respectively. Rai (1986) has reported that the west massif is bordered by Rajmahal-Garo lineament and eastern boundary is a NE-SW lineament separating the massif from the sediments of Bengal-Assam shelf. The southern parts of the Shillong plateau have experienced tremendous tectonic impacts giving rise to the steep scarp which today stands aloft facing the Sylhet plain of Bangladesh (Map 2.1).

Physiography

Based on the physiography, the state may be divided into (i) western region, (ii) central and eastern region, (iii) northern undulating hills, and (iv) southern precipitous zone. The western region includes Garo hills and western parts of west Khasi hills. The central and eastern region includes Khasi hills, Ri bhoi and Jaintia hills. The northern hill region is characterized by undulating hills towards the north with altitude ranging between 300 m and 1600 m asl, while the southern part is a high precipitous zone. The central upland zone constitutes the highest elevation zone of the Shillong plateau (Map 2.2).

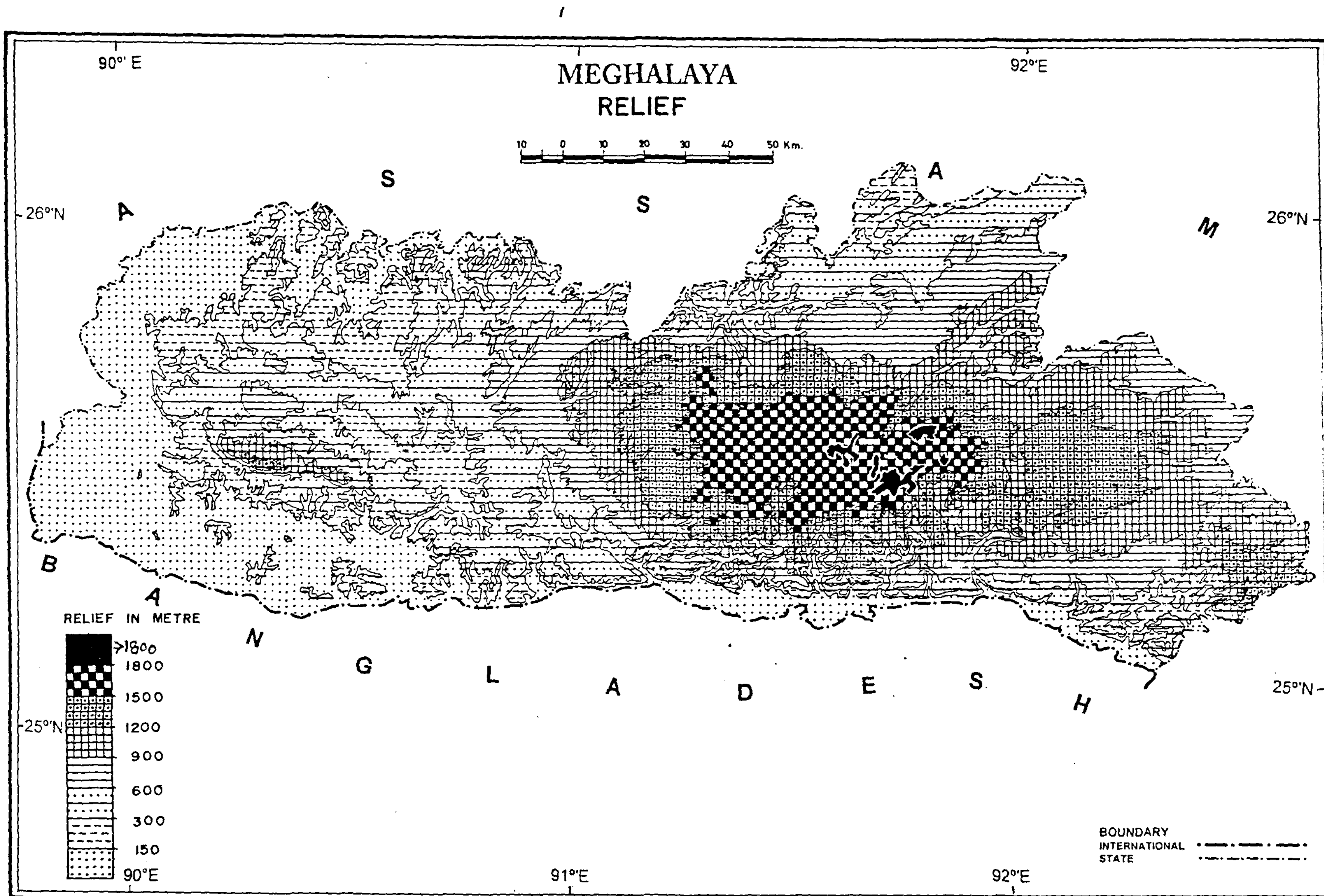
Soil

The soils of Meghalaya have been broadly grouped into four categories *viz.,* (i) red loamy soil, (ii) lateritic soil, (iii) red and yellow soil and (iv) alluvial



Geological Survey of India Publication, 1976

Map 2.1. **Map showing the geology of the state of Meghalaya.**

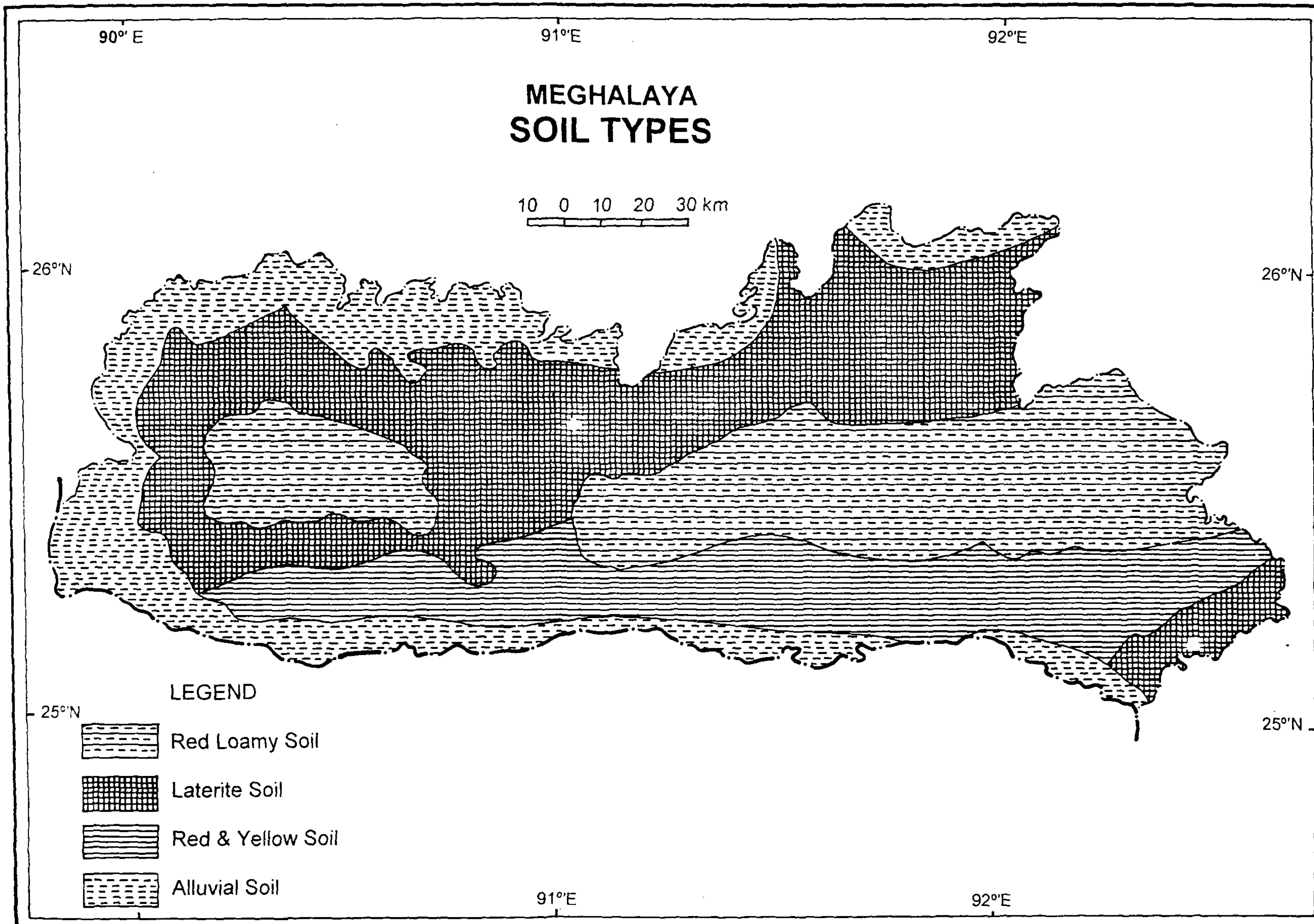


Map 2.2. Map showing the relief pattern of the state of Meghalaya.

soil (Map 2.3). The red loam soil is found in the central part of the Garo Hills and on the uplands of central and eastern Meghalaya. The lateritic soil occurs in the form of a broad belt extends from west to east in the northern part of the state. Red and yellow soil extending from west to east in the southern part. Alluvial soil occurs all along the northern, western and southern fringes of the state. The soils are acidic (pH 3 - 6.5) in nature. Acidity is attributed to the leaching of cations like calcium, magnesium and potassium from the soil due to high rainfall and undulating topography. Total Kjeldahl nitrogen content is low (*ca.* 0.15%) at degraded sites and fairly high (*ca.* 0.94%) in the undisturbed forests. Soils are deficient in available phosphorus (15 $\mu g\ g^{-1}$) and medium in available potassium (13 $\mu g\ g^{-1}$), and rich in organic carbon (1.62%). Soils are not suitable for intensive cultivation due to their poor base (35%) saturation (Singh 1996).

Climate

The climate of the state is monsoonic and is directly influenced by the southwest monsoon originating from the Bay of Bengal and Arabian Sea. The climatic variables like temperature, rainfall and humidity vary widely from place to place in the state due to wide variation in topography. Based on the atmospheric conditions, the year may be divided into summer, rainy, autumn and winter seasons. The summer (March end to mid May) is characterized by the relatively high temperature, occasional thunderstorms and high wind velocity. The rainy season commences with the onset of southwest monsoon in mid May and continues up to September. Three fourth of the total annual

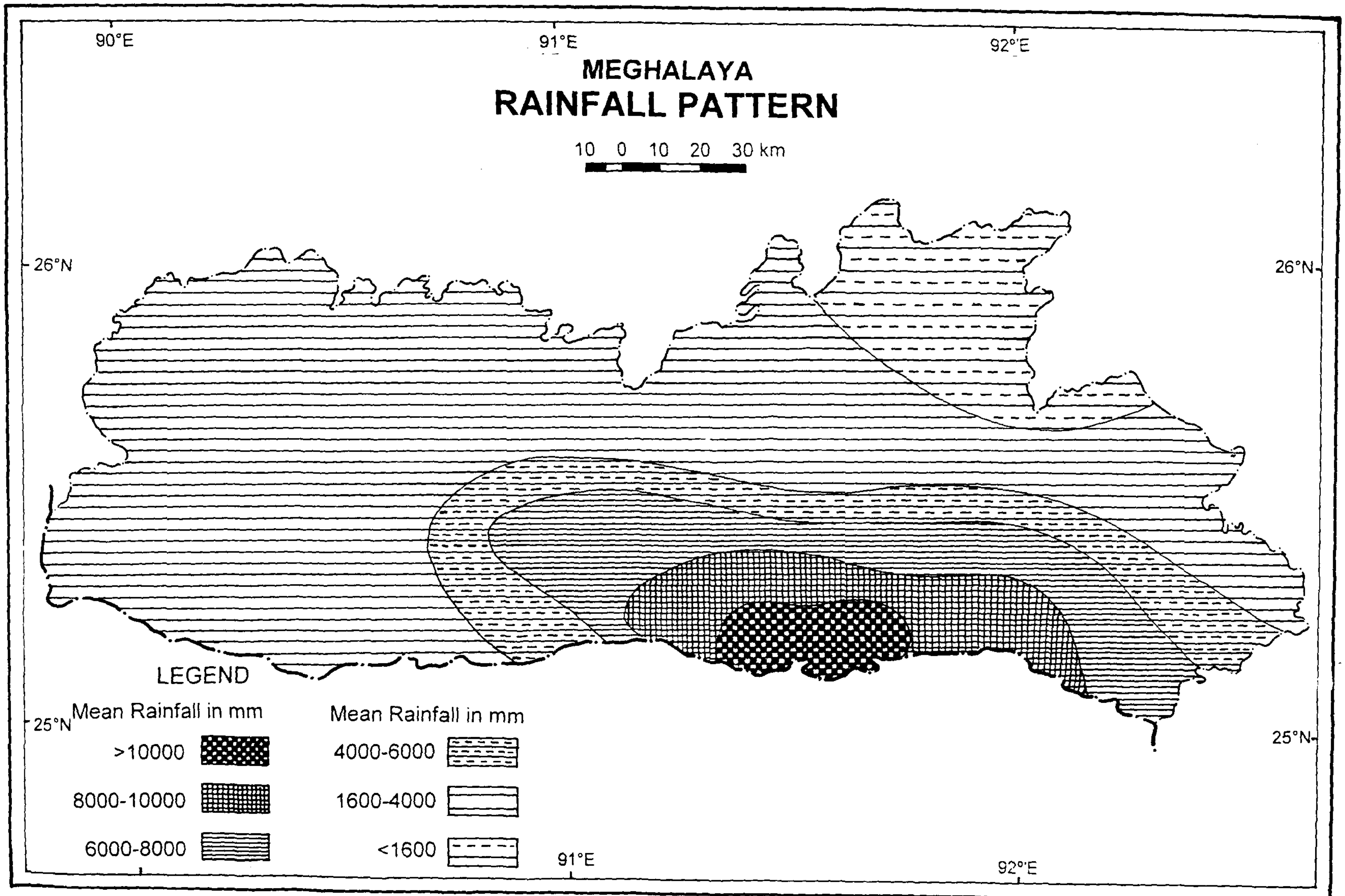


Map 2.3. Map showing the soil types of the state of Meghalaya.

rainfall is received during this season. The rainy season is followed by a brief autumn during October and November. Rainfall and temperature sharply decline during this period. The winter season, extends from December to February. Morning fog and frost, and dry weather are the characteristic features of this season.

The annual rainfall varies widely in the state ranging from about 1,600 mm (Umiam, Ribhoi) to over 11,463 mm (Mawsynram, East Khasi hills). The Ri bhoi district receives the lowest rainfall, while the northern part of Jaintia hills, Khasi hills and whole Garo hills receive between 1,600 and 4,000 mm rainfall annually where altitude ranges between 600 m to 1400 m asl. In southern Khasi hills (higher altitude), annual rainfall varies widely from 4,000 mm to 11,000 mm in different areas (Map 2.4).

The western part of the state is warm with mean temperature ranging between 12^0C and 33^0C. The central upland is relatively cooler where the mean minimum temperature drops to 5 ^{0}C and mean maximum temperature does not exceed 24 ^{0}C. The region experiences a tropical monsoon climate and receives both northeast and southwest monsoons. The climatic data for the five different meteorological station *viz.*, Tura (Garo hills), ICAR complex (Ri bhoi district), Upper Shillong and Cherrapunji (East Khasi hills), and Jowai (Jaintia hills) were collected for the period 1997 to 2001 and their mean values are shown in Fig. 2.1.



Map 2.4. Map showing the spatial variation *in annual rainfall* in the state of Meghalaya.

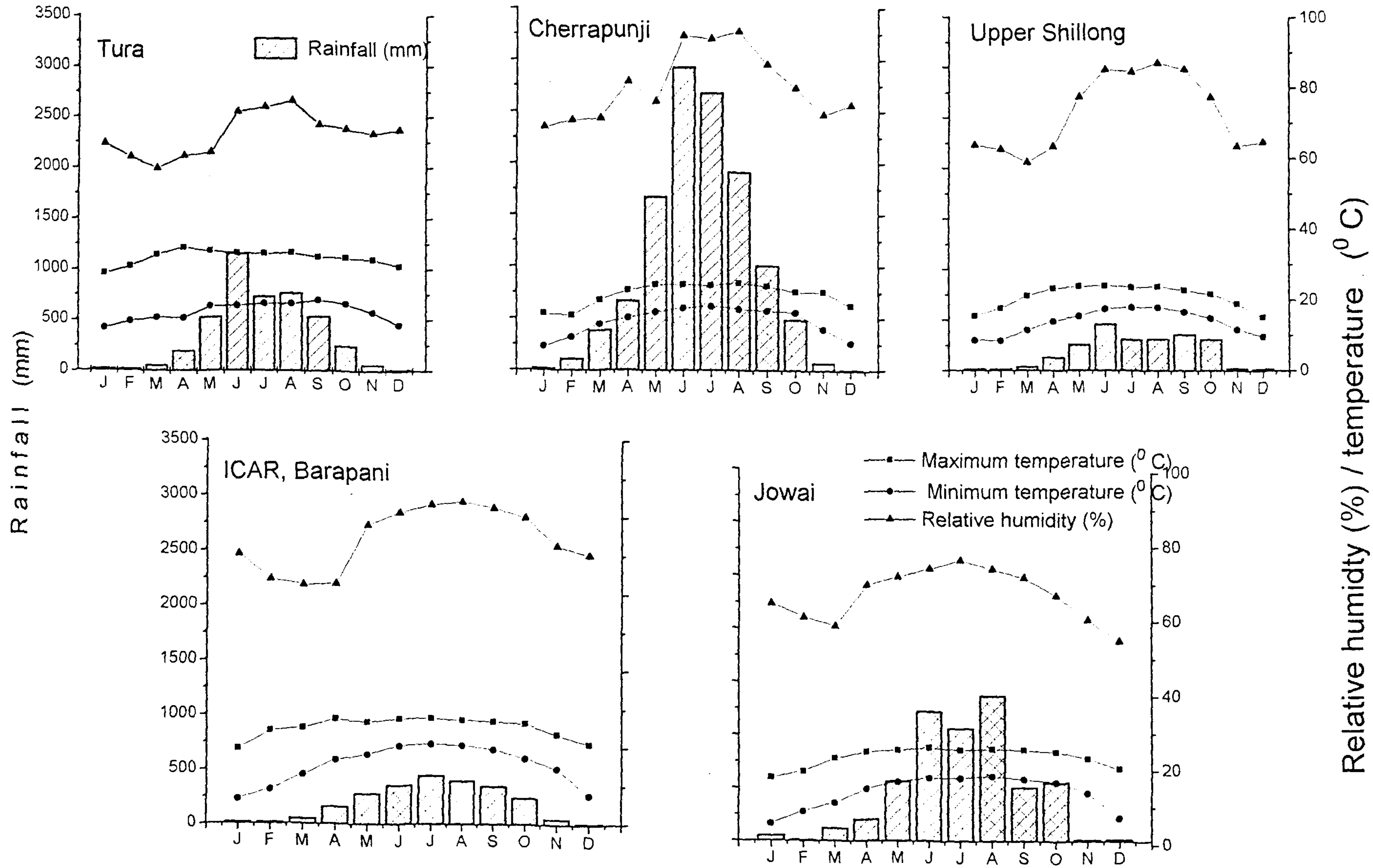


Fig. 2.1. Mean monthly rainfall (mm), relative humidity (%), mean maximum and minimum temperatures (^{0}C) of the state.

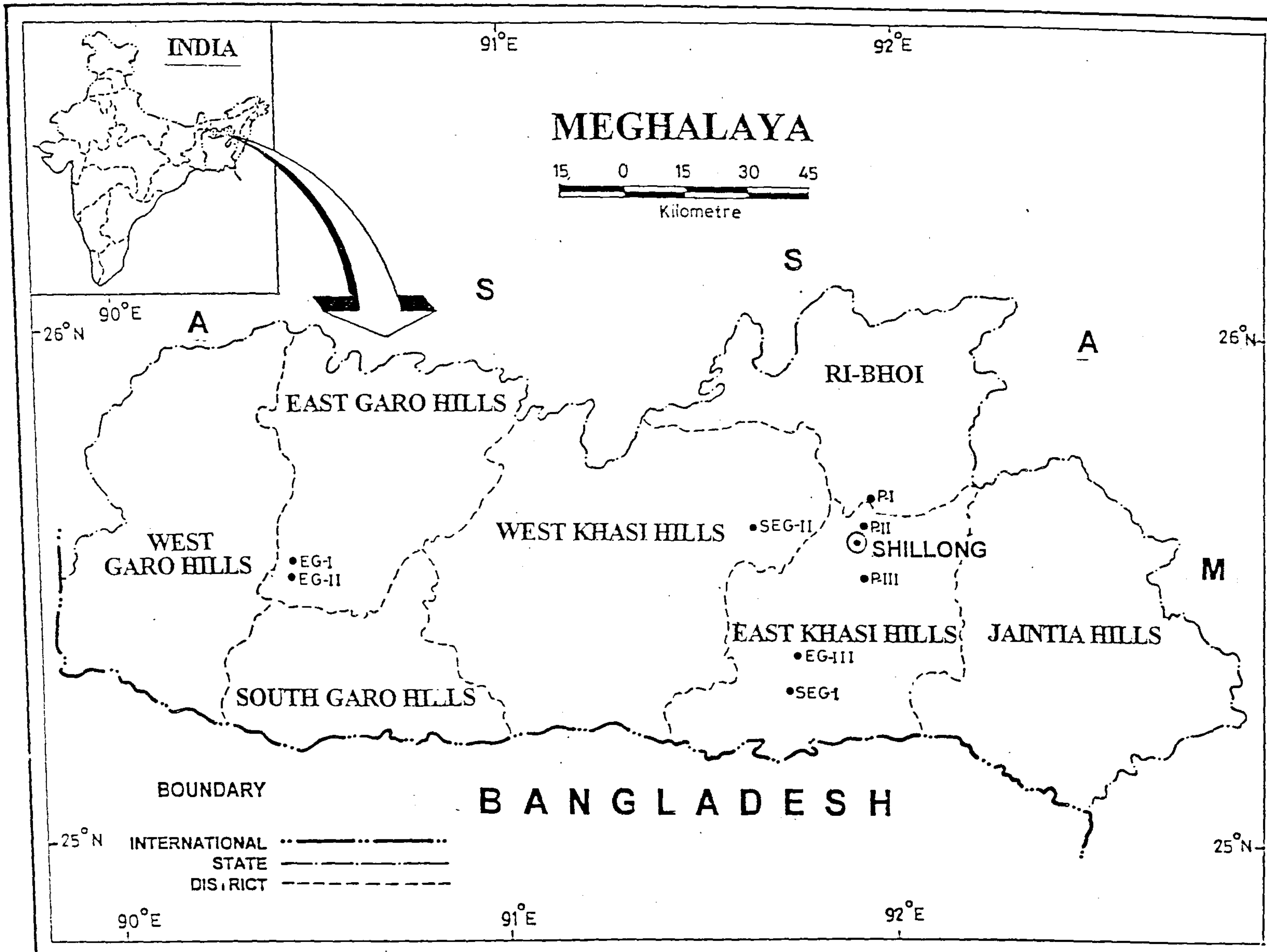
Study sites and Sampling procedure

Two to three study sites were selected along an altitudinal gradient for each of the three major forest types *viz.*, subtropical evergreen forest, subtropical semi-evergreen and subtropical pine forests (Map 2.5). These study sites and location along with their altitudes as well as their abbreviations used in the thesis are listed below (Table 2.1).

Soil analysis

Soil samples were collected randomly from the three depths *viz.*, 0-10, 10-20, and 20-30 cm at 5-10 places on annual basis from all representative stands of the above three forest types during October, 1999 and September, 2001. They were brought to the laboratory and mixed thoroughly to obtain a composite sample for each depth. These samples were air-dried, sieved through 2mm mesh and used for the analysis of Total Kjeldahl nitrogen (TKN), soil organic carbon (SOC), and available phosphorus.

TKN was determined by digestion and semi-micro distillation method following Allen *et al.* (1974). Soil organic carbon was determined by rapid titration method (Walkley and Black 1934). Soil organic matter was estimated by multiplying the organic carbon content by 1.724 assuming that soil organic matter contains 58% carbon (Allen *et al.* 1974). C/N ratio was calculated by dividing the percentage values of SOC by TKN values (in %). Available phosphorus was determined by molybdenum blue method (Anderson and Ingram 1993).



Map 2.5. Map showing the location of the study sites (•) in the state of Meghalaya.

Table 2.1. Representative sites selected under major forest types.

Forest type	Selected sites	Abbreviation used in thesis	Altitude (m asl)	Location
Subtropical evergreen forest	1. Nokrek Biosphere Reserve (Buffer zone)	EG - I	1,125	25^0 27' N and 90^0 18' E
	2. Nokrek Biosphere Reserve (core zone)	EG - II	1,425	25^0 27' N and 90^0 19' E
	3. Swer sacred grove	EG - III	2,035	25^0 25' N and 91^0 47' E
Subtropical semi-evergreen forest	1. Mawlong sacred grove	SEG - I	1,475	25^0 14' N and 91^0 43' E
	2. Mawiong sacred grove	SEG - II	1,748	25^0 33' N and 91^0 38' E
Subtropical pine forest	1. Mawpun, near ICAR complex	P - I	1,058	25^0 40' N and 91^0 54' E
	2. Permanent Campus, NEHU	P - II	1,460	25^0 34' N and 91^0 54' E
	3. Upper Shillong	P - III	1900	25^0 32' N and 91^0 53' E

Soil pH was determined electrometrically by digital pH meter using 1:2.5 suspension of soil and water (Anderson and Ingram 1993). Moisture content was determined gravimetrically by drying 10 g of field-moist soil at 105 ^{0}C for 24 hours in a hot air oven (Allen *et al.* 1974).

Vegetation studies

Distribution and land area coverage of subtropical evergreen, subtropical semi-evergreen, and subtropical pine forests were determined using Geographical Information System (GIS) with the help of imagery procured from

Indian Institute of Remote Sensing (NRSA), Dehra Dun. The imagery IRS 1D LISS-III for the period of 2000 was used for this purpose.

Biodiversity studies

The representative forest stands in each of three forest types were sampled by using square quadrats of different sizes *viz.*, 30 quadrats of 20 x 20 m for tree species, 30 quadrats of 5 x 5 m for shrubs / tree saplings (5-15 cm cbh) and 120 quadrats of 1 x 1 m for herbaceous species / tree seedlings (<5 cm cbh). Plant species were collected and identified with the help of different floras (Kanjilal *et al.* 1934-40, Balakrishnan 1981-83, Haridasan and Rao 1985-87). Herbaria of Botany Department, North-Eastern Hill University and Botanical Survey of India, North-Eastern Circle, Shillong were consulted from time to time for correct identification of the plant species.

Vertical and horizontal distribution pattern of species

Vertical distribution pattern of species in the community (stratification) was studied by drawing profile diagram along a belt transect 30 m long and 5 m wide. All plants having more than 15cm cbh were considered for preparing profile diagram. Tree height was measured with the help of a clinometer (Sunnto pm-5/1520).

Horizontal distribution pattern of the species in the forests was studied by computing Whitford's index (Whitford 1948):

$$\text{Whitford index} = \frac{\text{Abundance (A)}}{\text{Frequency (F)}}$$

The distribution was considered regular, if the value for the index was (< 0.025), random if the index ranged from 0.025 to 0.05, or contagious or clumped if the value was > 0.05.

Life form spectrum

Plant species were grouped into five major life forms *viz.*, phanerophytes, chamaephytes, hemicryptophytes, geophytes or cryptophytes and therophytes as outlined by Raunkier (1934) and Mueller-Dombois and Ellenberg (1974). Life form spectrum was worked out site-wise. Further, the data were pooled to prepare life form spectra of the three major forest types. The percentage of species belonging to each life form was determined by the following formula:

$$\text{Percentage of species in life form} = \frac{\text{Number of species in a given life form}}{\text{Total number of species of all the life forms}} \times 100$$

Frequency, density, basal cover and IVI

Field data for computing frequency, density, basal cover and importance value index of plant species were collected by randomly laying the quadrats of different sizes as mentioned under the caption 'biodiversity studies' and the values were calculated following Misra (1968) and Mueller-Dombois and Ellenberg (1974).

Family Importance Value (FIV)

FIV for tree species was calculated at all sites using the following formulae (Keel *et al.* 1993). The relative values were calculated as follows:

$$\text{Relative density} = \frac{\text{Total number of individuals in a family}}{\text{Total number of individuals in all families}} \times 100$$

$$\text{Relative diversity} = \frac{\text{Total number of species in a family}}{\text{Total number of species in all families}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of a family}}{\text{Total basal area of all families}} \times 100$$

FIV = relative density + relative diversity + relative dominance

Species richness, diversity, dominance and evenness indices

Species-richness was assessed by computing Whittaker α-diversity (Whittaker 1960, 1975).

$$D = \frac{S}{\ln N} \times 100$$

Where,

D = Whittaker α-diversity

S = Number of species in a sample

N = Total number of species in the sample

Whittaker β-diversity (Whittaker 1960, 1975) was used to compare the species diversity between the different forests. It was calculated as:

$$\beta_w = \frac{S}{\alpha} - 1$$

where,

β_w = Whittaker Beta diversity,

α = Species richness (mean),

S = Total number of species.

Shannon and Wiener (1963) index of diversity ($\bar{H}$) was calculated using IVI values of the species.

$$\bar{H} = -\sum_{i=1}^{s} (ni / N) \ln (ni / N)$$

where,

ni = IVI of the i^{th} species,

N = IVI of all the species.

Simpson dominance index (Simpson 1949) was calculated by using IVI values of the species.

$$D_s = -\sum_{i=1}^{s} (ni / N)^2$$

where,

D_s = Simpson dominance index

ni = Importance value of the i^{th} species,

N = Importance value of all the species.

Evenness index (E) was calculated following Pielou (1975).

$$\text{Evenness index (E)} = \frac{\bar{H}}{\ln S}$$

where,

$\bar{H}$ = Shannon diversity index,

S = Total number of species.

Tree population structure and regeneration

Population structure was studied on the basis of girth-class distribution pattern (Khan and Tripathi 1992) whereas regeneration was assessed on the basis of density of seedlings, saplings and adult trees in the population (Khan *et al.* 1987, Uma Shankar 2001).

CHAPTER III

REVIEW OF LITERATURE

Forests cover about 26.7% (129 million sq. km) of the total land area of the world (FAO 1995, 1997). Between 1980 and 1995, the world forests have decreased by 180 million hectare. This represents a global annual loss of 12 million hectare. Developing countries have lost nearly 200 million ha of natural forests, mostly through shifting cultivation. Forests losses were relatively slow (*ca.* 20 million ha) in the developed countries (Evans 2001). Among the land communities the tropical forests are most ancient, diverse and complex (Lewin 1986), covering about 7% of the earth's surface (Myers 1984).

Most of the tropical forests have some history of land use by humans (Flenley 1979, Horn and Sanford 1992). The anthropogenic interventions have resulted in changes in vegetation composition and distribution pattern of forest in time and space (Browker, 1987). Temporal changes in most landscape pattern are dictated by combination of natural and human influences that operate at different spatial and temporal scales. Increasing human population and demands for land and other forest resources have created a plethora of deleterious effects on these communities (Laurance and Bierregaard 1997). The effects of deforestation include massive soil erosion, siltation, and loss of sustainable forests, threats to indigenous people and destabilization of watersheds (Smith 1981).

The tropical and subtropical forests together have major proportion of plant species found on the earth (WCMC, 1992) and, therefore, are the best representatives of the species rich forest (Gentry 1988, Valencia *et al.* 1994, Ashton and Hall 1992). Unfortunately, most of these forests are reeling under severe threats of destruction due to various anthropogenic activities and in many places they have been reduced small patches in the form of reserves, parks or other protected areas, which serve as refugia for the fast depleting flora.

Forest structure and composition are strongly correlated with environmental factors, such as climate and topography (Wright 1983, Currie 1991). Quantitative inventories provide information on the nature of species diversity of forests, as well as precise information on the structure of the ecosystems (Phillips and Gentry 1994). Floristic inventories and study of forest dynamics usually relay on sampling plots (Dallmeier 1992). The estimates of plant diversity depend on plot size (Kilburn 1966, Grieg-Smith 1983) and plot shape (Condit *et al.* 1996, Laurance *et al.* 1998). Most studies have followed the plot method, using either square plots (Campbell *et al.* 1986, Gentry 1990) or rectangular plots (Prance 1976).

Tree diversity has attracted the attention of many ecologists to understand the patterns and processes relating to tropical forest diversity (Condit *et al.* 1996). Studies on tropical tree diversity have accumulated over past decades and comprehensive review papers have been published on the subject (Gentry 1990, Phillips *et al.* 1994, Condit *et al.* 2000).

Tree diversity inventories have employed a wide range of sampling protocols that vary in tree size threshold considered for sampling, and number, shape and size of plots. Tree size (dbh, cbh or gbh at 1.3m above the ground level) has been considered as a criterion for mensuration. There are studies that have included the enumeration of tree individual as small as 2.5 cm dbh (Knight 1975) through 4.5cm dbh or 15cm cbh (Bunyavezchewin 1999), 5cm dbh (Pelissier and Rierra 1993, Valencia *et al.* 1994, Johnston and Gillman 1995, Upadhaya *et al.* 2002), 15 cm dbh (Prance *et al.* 1976), to 30 cm dbh (Nadkarni *et al.* 1995).

Bongers *et al.* (1988) have used the lowest limit of dbh (1cm) for the assessment of tree diversity in the lowland rainforests of Los Tuxtlas, Mexico. There are many studies that have used tree height as a criterion to measure tree diversity (Rodrigues 1961) in which all trees having ≥ 1m heights were inventoried. Prance (1979) considered all plants having >3 m height or >5 cm dbh as trees and woody plants, between 1.3 m to 3 m height as shrubs and non-woody plants, and smaller than 1.3 m as herbs.

Quantitative inventories of species-rich tropical and subtropical forest flora in different parts of the world have been prepared by several workers such as Sukumar *et al.* (1992), WCMC (1992), Phillips *et al.* (1994), Felfili and Maria (1995), Johnston and Gillman (1995), Vishalakshi (1995), Lieberman *et al.* (1996), Elouard *et al.* (1997), Ganeshaiah *et al.* (1997), Joshi *et al.* (1997), Parthasarathy and Sethi 1997, Kadavul and Parthasarathy (1999), Jamir (2000), Uma Shankar (2001), Upadhaya *et al.*(2002).

Diversity of a community can be assessed by a variety of nonparametric measures such as Shannon, Simpson, Margalef indices, and these measures have gained a great deal of popularity in the recent past (Maguran 1988, Krebs 1989). Besides species diversity, abundance of species in community that helps in determining the common and rare species (May 1975) have been studied by several workers such as Harte *et al.* (1999), Kunnin *et al.* (2000) and Jamir (2000).

The concept of dominance, that is, the idea that certain species so pervade the ecosystem that they exert a powerful control on the occurrence of other species, is one of the oldest concepts in ecology. McNaughton and Wolf (1970) opined that dominance is an expression of ecological inequalities arising out of different exploitation strategies. Hart *et al.* (1999), Connel and Lowman (1989) and Hart (1990) have studied the possible mechanism to maintain dominance in the forest community.

The spatial distribution of individuals of a species is central in ecology theory (Dale 1999). Plant populations exhibit three patterns of spatial distribution *i.e.* regular, random and contagious or clumped. Patchiness or the degree, to which individuals are aggregated or dispersed, is crucial to how a species uses resources. Webb *et al.* (1967), Ashton (1972) and Austin *et al.* (1972) indicated that in the absence of major disturbance, soil and water conditions play major roles in controlling species distribution. The spatial scale of natural disturbances and the time frame involved, play significant role in determining the frequency of clumping and randomness in forest communities (Armesto *et al.* 1986).

Population ecology of tree species has been studied in many tropical and subtropical forests (Swaine *et al.* 1987, Connell and Lowman 1989, Hart 1990). Ecologists often use girth class distribution to indicate the health of population. Population structure data for tree species such as size and density of individuals (Lamprecht 1962), and vertical distribution (Finol 1971) are necessary for interpretation of forest structure. Presence of a larger number of saplings than adult trees indicates that a population is growing or stable, whereas less or fewer number of saplings indicates that the population is declining. Population studies in forest ecosystems have been used to infer past changes and predict future changes in species composition by examining the size class distribution of woody species (Harte *et al.* 1989, Franklin *et al.* 1993, Read *et al.* 1995). Presence of less number of saplings of a species in the forest stand is a major concern for its conservation (Foster *et al.* 1996).

The girth-class composition of stands at high disturbance level resembles J-shaped distribution (number increases with increasing age), which indicates future decline in the population (Knight 1975). However, at low disturbance, the trend is considerably reversed due to presence of a large number of individuals in lower girth-class, an indicator of a growing population (Pandey and Shukla 2001).

Tree regeneration includes both seedling recruitment and sapling development. Factors likely to affect tree regeneration in tropical forests includes parental tree fecundity (John 1993), pre-dispersed losses, availability of suitable germination sites, early survivorship, and losses due to predation, herbivory, pathogens, presence of competitors, and access to resources.

Whitmore (1975), Streng *et al.* (1989), Webs *et al.* (1972), Welden *et al.* (1991) and Okuda *et al.* (1997) have studied natural regeneration of trees in the tropical forest. Survival and growth of tree seedlings and sprouts depend upon the interactive influence of several biotic and abiotic factors of the forest environment (Khan *et al.* 1987). The effects of certain factors like light intensity (Augspurger 1984, Burton and Mueller-Dombois 1984, Rao *et al.* 1990), temperature (Sorensen and Ferrell 1973), Soil moisture (Mueller-Dombois *et al.* 1980, Schutle and Marshal 1983), soil nutrients (Kliejunas and Ko 1974, Mullin and Browdery 1977), and pathogens (Augspurger 1984, Connel *et al.* 1984) have been studied on survival and growth of tree seedlings in tropical, subtropical and temperate forests.

Significance of under-canopy vegetation in determining the size of seedling populations of trees through mortality has been emphasised by Cross (1981), Eis (1981), Maguire and Forman (1983), and Connel *et al.* (1984). The under-canopy vegetation may also influence seedling survival of tree species through their allelophathic effects, as reported by Rice (1974), Stewart (1975), Willis (1980) and Ashton and William (1982). Topography also influences the natural regeneration. The erosive action of the torrential rain received on the hilltops decreases population size of tree seedlings during rainy season (Khan *et al.* 1987).

Regeneration status of trees can be predicted by age structure of their population (Saxena *et al.* 1984, Khan *et al.* 1987). Presence of sufficient number of seedlings and young trees in a given population indicates better regeneration (Saxena and Singh 1982). Khan *et al.* (1986) have studied regeneration status and survival of tree seedlings and sprouts in deciduous and subtropical forests of Meghalaya and reported better seedling and sprout survival at the periphery as compared to the dense forest. Rao (1992) studied gap phase regeneration in a subtropical broad-leaved climax forest of Meghalaya. Tripathi and Khan (1992) studied regeneration pattern and population structure of tree species in subtropical forest of Meghalaya in northeast India.

Disturbance is a common and widespread phenomenon in nature that modifies landscape, ecosystem, community and population structure (White and Pickett 1985). The disturbance also leads to habitat fragmentation. Fragmentation reduces the area of core habitat, divides the larger continuous forest patches into smaller ones, isolating the remnants of original ecosystems (Hobbs *et al.* 1989), and leads to the loss and extinction of several plant species (Tilman *et al.* 1994, Burkey 1995). Fragmentation of ecological units has been well documented at landscape level using patch number, size, shape, abundance and forest matrix characteristics (Ripple *et al.* 1991, Skole and Tucker 1994, Ravan and Roy 1995, Roy and Tomer 2000).

Bierregaard *et al.* (1992) and Ravan and Roy (1995) have studied fragmentation of tropical forest and its impact on species composition. As a result of fragmentation, there is greater probability of biodiversity loss in the tropical regions than in temperate regions (Turner and Corlett 1996).

Laurance *et al.* (1998) found that fragmented gallery forest preserved diverse tree flora. Virolainen *et al.* (1998) concluded that large patches should be protected to maximize species diversity. Ganeshaiah (1997) found that there is low species similarity in small as compared to medium and large forest patches in the Western Ghats.

Habitat destruction is the major cause of species extinctions (Ehrlich and Ehrlich 1981, Wilson 1988, Simberloff 1984). Dominant species often are considered to be free from this threat because they are abundant in the undisturbed fragments that remain there after destruction. The moderate habit destruction is predicted to cause time-delayed but deterministic extinction of the dominant competitor in the remnant patches. Moreover, the more fragmented a habitat already is, the greater is the number of extinctions caused by added destruction.

Both habit loss and fragmentation are usually thought to negatively affect species persistence (Herben *et al.* 1991, Noss 1991, Adler and Nuernberger 1994). Fahring and Merriam (1994) predicted negative impact of fragmentation, that includes increased mortality of individuals moving between patches, lower recolonisation rates of empty patches, and reduced local population size resulting in increased susceptibility to extinction. Kareiva (1987) and Roland (1993) reported that habitat fragmentation has a positive effect on regional population survival.

Forest fragmentation may affect seedling abundance through increased tree mortality (William-Linera 1990, Laurance 1991, Bierregaard *et al.* 1992, Chen *et al.* 1992, Essen 1994) due to drastic change in relative humidity and temperature (Kapos 1989, Camargo and Kapos 1995). Small-scale disturbances, such as tree falls, alter forest microclimate and microsite heterogeneity significantly so much so that it may affect community dynamics (Nunez-Farifan and Dirzo 1985, McCarthy 1990), and play important role in maintaining species richness in the forest.

India has a great geographical expanse that has resulted into enormous ecological diversity ranging from sea level to high mountain ranges, hot-arid climate in the west to humid and perhumid climate in the northeast and Western Ghats and cold-arid conditions in the Trans Himalayan region. As a result, India has a representation of 12 bio-geographical provinces, five biomes and three bioregions (Bailey 1989, Cox and Moore 1993).

The geographic location of the country at the confluence of three major global bio-geographic realms *viz.*, Indo-Malayan, Eurasian and Afro-Tropical further enhances its biological attributes. This has allowed the intermingling of floristic elements from these regions, making it one of the 12 mega-diversity centers, ranking third in Asia and eleventh in the world with a share of about 11% of latter's total floristic resources (Sharma and Singh 2000).

The state of Meghalaya is reported to have 3,128 species of plants including 1,236 endemic species (Khan *et al.* 1997). The rich plant diversity of the state has attracted the attention of the eminent botanists from all over the world (Haridasan and Rao 1985). Kanjilal and co-workers (1934-40) were the first Indians to have studied the flora of this region and Myrthong (1980), Balakrishnan (1981-83), Kumar (1984) and Haridasan and Rao (1985-87) have contributed to the understanding of the flora of Meghalaya.

Remote sensing technology is very useful in locating different types of bio-resources to identify appropriate corridors surrounding natural habitats and to protect them from human interventions and other harmful influences that endanger the existence of these habitats. Using different landscape ecological parameters along with ground observations, biologically rich areas, hotspots *etc.*, can be identified. Recent advances in remote sensing and geographical information systems have offered new opportunities for investigation at larger scale.

Satellite images are considered as a very convenient tool to measure landscape pattern. The technology helps in extracting maximum amount of vegetal information that describe vegetation diversities i.e., extent, structure, cover, composition, biomass / production *etc.* Though each of them can be measured on ground, they may be interpreted more effectively from satellite imagery (Tomar 1998). Satellite remote sensing has played a key role in providing information about large-scale deforestation in many parts of the tropics (Skole and Tucker 1994). A major contribution of the technology is its capability to understand land-use change dynamics.

Northeast region is one of the most important landscapes of India, dominated by varied forest types and associated land-use. Though shifting cultivation has long been practiced throughout the region, changes in land use over past few decades due to shifting agriculture have resulted in permanent structural and compositional changes in the vegetation types (Roy and Tomer 2001). Meghalaya has witnessed significant rate of change in the landscape during 1980-1989 compared to 1989-1995 (Roy and Tomer 2001). The land transformations have resulted in the alteration of natural habitats by forest fragmentation and degradation of sites.

Classifying vegetation is an important component in the management and planning of natural resources. Classification of Indian vegetation particularly the forest types was given by Champion (1936), which was, later on, revised for present-day India by Champion and Seth (1968). They recognised 16 major forest types and subdivided them into 221 minor types on the basis of structure, physiognomy and floristic composition. Puri *et al.* (1983) have classified the Indian vegetation according to successive dryness of the habitat, and biotic types that are secondary in origin are, therefore, recognised as distinct from climatic and edaphic types of Champion and Seth (1968).

The vegetation of the state of Meghalaya has been classified by different workers such as Kanjilal *et al.* (1934-40), Champion and Seth (1968), Balakrishnan (1981-83), Haridasan and Rao (1985-87), Rao and Hajara (1986) and Chauhan and Singh (1992). They have divided the vegetation into tropical evergreen forest, tropical semi-evergreen forest, subtropical broad-leaved hill forest, tropical moist deciduous forest, temperate and subtropical pine forest and savanna based on site condition and floristic composition.

Remote sensing not only helps in identifying different forest types and their distribution but also helps in identifying species rich areas at landscape level and the changes in land use pattern. As per IRS 1D data (2000) six major forest types *viz.,* tropical moist deciduous, subtropical evergreen, subtropical semi-evergreen, subtropical pine, subtropical mixed pine and subtropical degraded pine forests have been recognised in the state.

Studies on the distribution pattern, fragmentation and community characteristics of the major forest types of the state have not been attempted at the landscape level, though plant diversity, tree regeneration, litter and fine roots and microbial dynamics in subtropical humid forests have been investigated by the earlier workers such as Khan *et al.* (1987), Rao *et al.* (1990), Barik (1992), Tripathi and Khan (1992), Arunachalam (1996), Barik *et al.* (1996), John (1998), Jamir (2000) and Upadhaya *et al.* (2002).

CHAPTER IV

Forest Types of Meghalaya: their distribution, Climate and Soil

India possesses almost all major types of natural forest ecosystems. The panorama of Indian forests ranges from evergreen tropical rainforests in the Andman and Nicobar Islands, the Western Ghats, and the northeastern states to dry alpine scrub in the Himalaya. Between the two extremes the country has semi-evergreen rain forests, deciduous monsson forests, thorn forests, subtropical pine forests in the lower montane zones and temperate montane forest (Lal 1989).

One of the most important forest classifications for greater India was given by Champion (1936) and later on revised for the present-day India by Champion and Seth (1968). They recognised 16 major forest types mainly on the basis of climatic factors and subdivided them into 221 minor types on the basis of structure, physiognomy and floristic composition. Puri *et al.* (1983) while broadly agreeing to their classification, have argued that biotic factors such as shifting cultivation, fire and grazing have played important role the development, floristic composition and stability of forest community in India.

The tropical forests are mainly found in the Andman and Nicobar Islands, the Western Ghats and in the northeast. Semi-evergreen rain forests are more extensive than the evergreen formation partly because evergreen forests tend to degrade to semi-evergreen type with human interference. The tropical vegetation of northeast India (which includes the states of Assam, Nagaland, Manipur, Mizoram, Tripura and Meghalaya as well as plain region of Arunachal pradesh) typically occurs at elevation up to 900 m. It embraces evergreen and semi-evergreen rain forests, moist deciduous monsoon forests, riparian forests, swamps and grasslands. Evergreen rain forests are found in Assam valley, the foot hills of eastern Himalaya and lower parts of the Naga hills, Meghalaya, Mizoram and Manipur where the rainfall exceeds 2000 mm per annum (IUCN 1991).

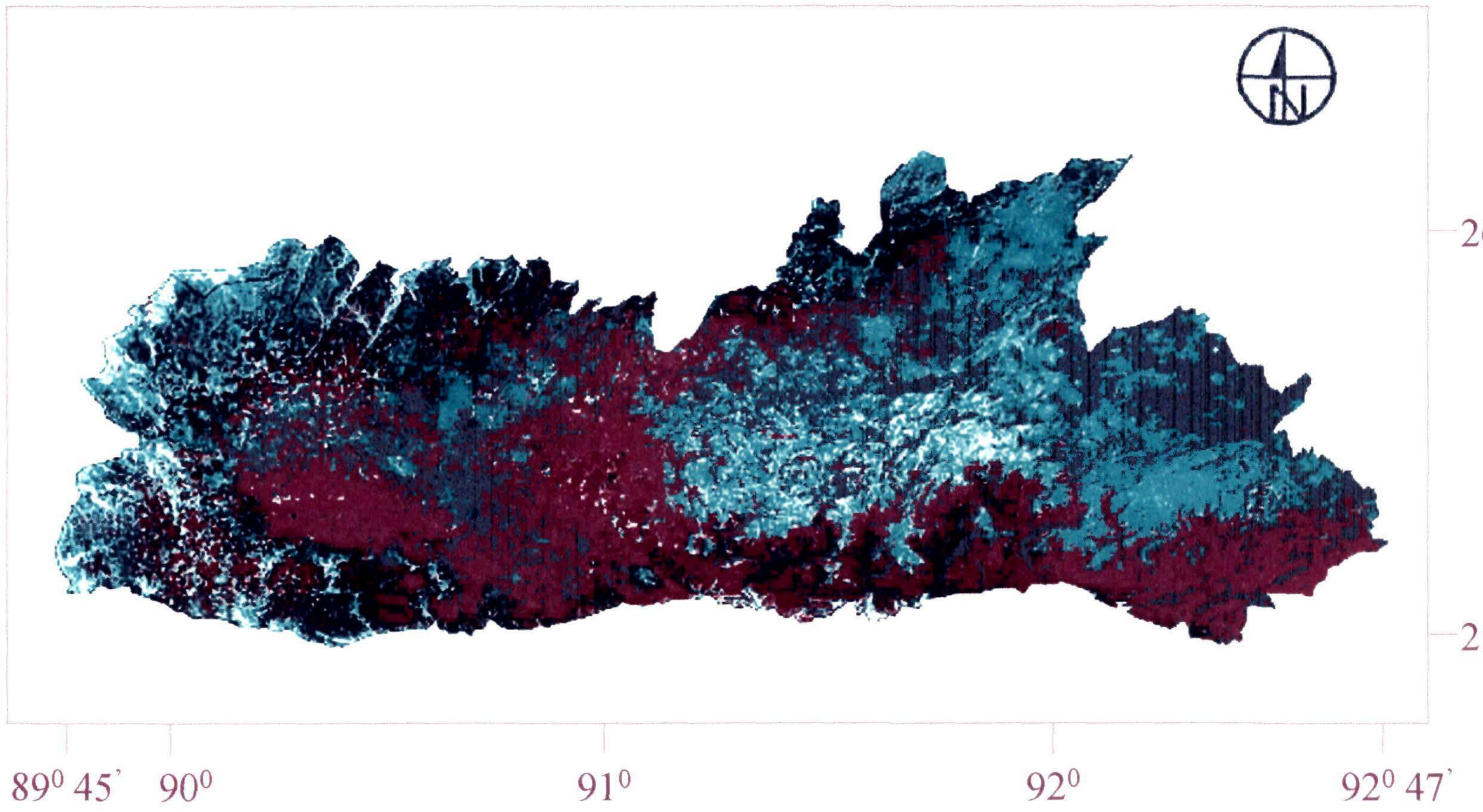
The vegetation of Meghalaya has been classified by Kanjilal *et al.* (1934), Champion and Seth (1968), Balakrishnan (1981), Haridasan and Rao (1985), Rao and Hajara (1986) and Chauhan and Singh (1992). They have divided the vegetation into tropical evergreen forest, tropical semi-evergreen forest, subtropical broad-leaved hill forest, tropical moist deciduous forest, temperate and subtropical pine forest and savanna based on site condition and floristic composition.

Satellite remote sensing has played a pivotal role in generating information about forest cover, vegetation types and land-use change (Roy *et al.* 2002). National Remote Sensing Agency (NRSA) for the first time used satellite remote sensing technique to map forest cover of India, including Meghalaya (Anonymous, 1984). Subsequently, Forest Survey of India (FSI), under its programme of biannual mapping of India has been mapping forest cover of the state since 1987.

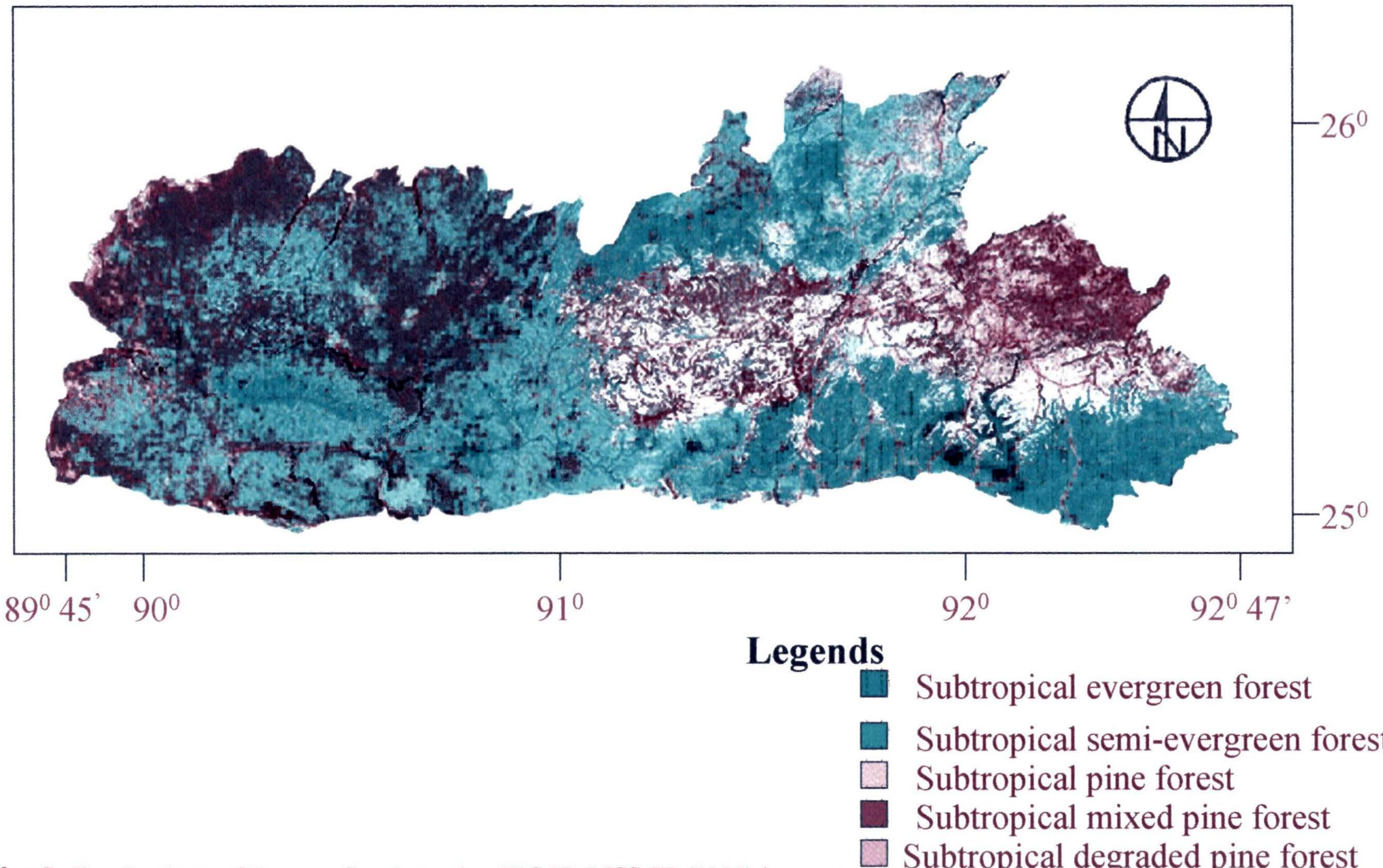
According to FSI Report (1999), forests cover about 19.2% of the geographical area of the country, of which primary forests are probably less than 1% (Mani, 1974). The vegetation cover of the state in 1999 was 15,633 square km, or 69.7% of the total geographical area of the state (FSI 1999). Dense forest occupies 5,925 square km (26.4%) and open forest occupies 9,708 square km (43.3%) of the vegetation cover. The biosphere reserve, reserve forests, protected forests, national parks and wildlife sanctuaries together cover about 300 square km area.

Based on the IRS ID data of 2000, six major forest types have been recognised in the state (Map 4.1, 4.2). They together cover 42.2% of the geographical area of the state. Out of these, the subtropical evergreen forest, subtropical semi-evergreen forest, tropical moist deciduous forest, and subtropical pine forest cover 11.6%, 21.5%, 1.3% and 7.8% of the total geographical area, respectively.

The tropical forest occurring below 1000 m may be either evergreen or semi-evergreen type depending on the dominance of evergreen and deciduous trees in the canopy. The subtropical forest found above 1000 m is either broad-leaved or needle-leaved. Small pockets of subtropical evergreen broad-leaved forest are found where rainfall is relatively high and soil moisture condition remains favourable for most part of the year, while those areas which receive relatively low annual rainfall support semi-evergreen forest. Pine forests have developed as a stable secondary community on the disturbed evergreen and


N
26⁰
25⁰
89⁰ 45'
90⁰
91⁰
92⁰
92⁰ 47'

Map 4.2. Classified vegetation map of the state of Meghalaya showing major forest types.



Classified at Indian Institute of Remote Sensing using IRS ID LISS III (2000) imagery semi-evergreen subtropical broad-leaved forest sites, which are seasonally dry and nutrient-poor (Fig. 4.1).

The primary tropical and subtropical forests of the state have been destroyed to a great extent by age-old tradition of shifting agriculture, which is extensively practiced in the state even today. As a result of this and other human activities, extensive degradation of the forest has taken place in the state. The degraded forestlands support a variety of successional communities ranging from weed-dominated communities on recently abandoned Jhum fields to pine forest and grassland on frequently burnt and nutrient-deficient sites (Fig. 4.2).

A brief description of the distribution, climate, soil and fragmentation of the four major forest types *viz*., tropical moist deciduous, subtropical evergreen, subtropical semi-evergreen, and subtropical pine forests have been given in the ensuing pages of this chapter.

Distribution and Species Composition

The study was conducted in five major forest types *viz.,* tropical moist deciduous, subtropical evergreen, subtropical semi-evergreen and subtropical pine forests. The distribution and area under each forest type was determined on the basis of classified forest type map of IRS ID (2000) data using ILWIS software and Curvy-meter. Classified map showing different vegetation types and their distribution is shown in Map 4.2. The area of forest patches under each type was calculated and they were grouped into different size classes based on their area.

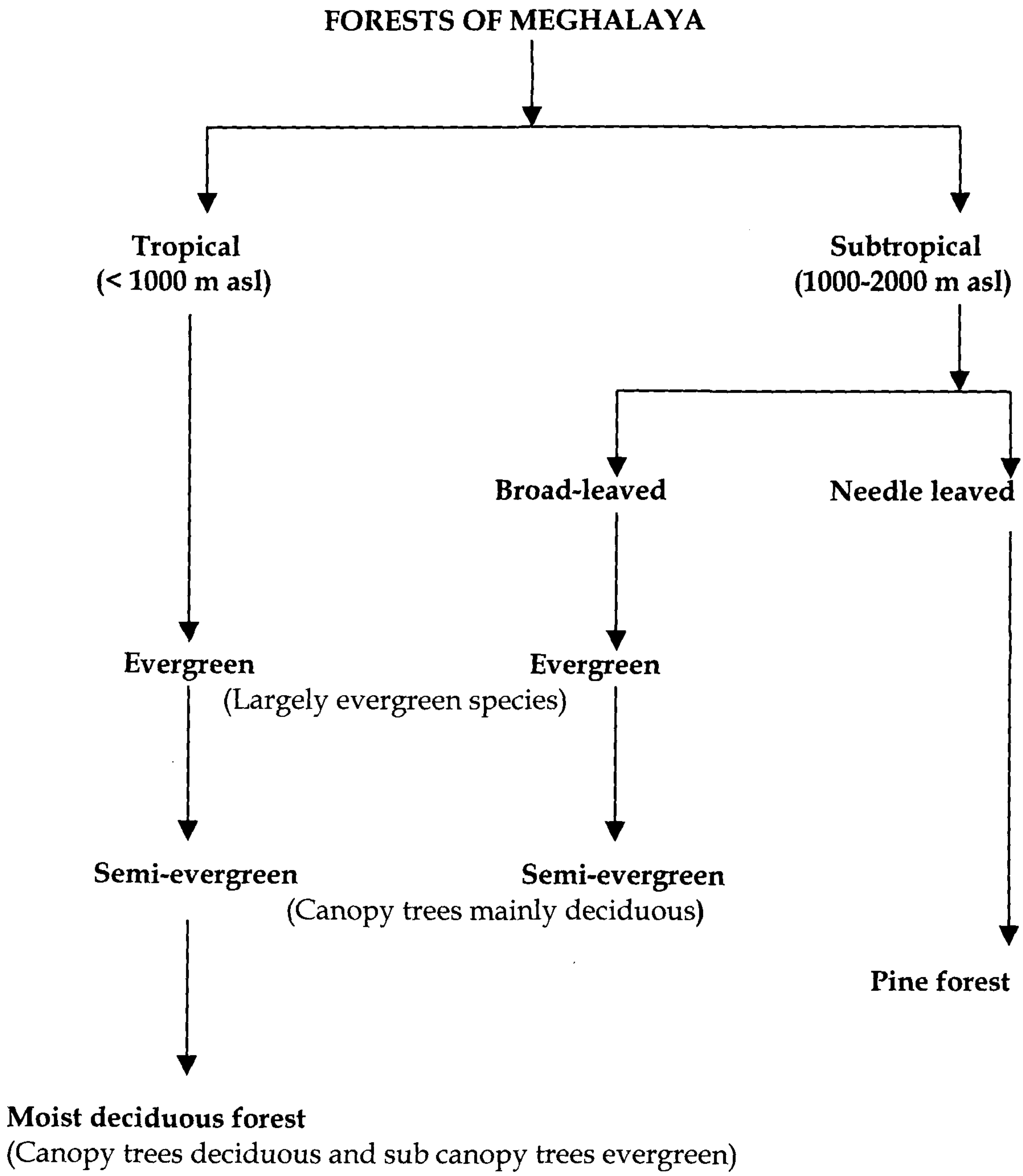


Fig. 4.1. Classification of major forest types of Meghalaya based on altitude and tree species composition.

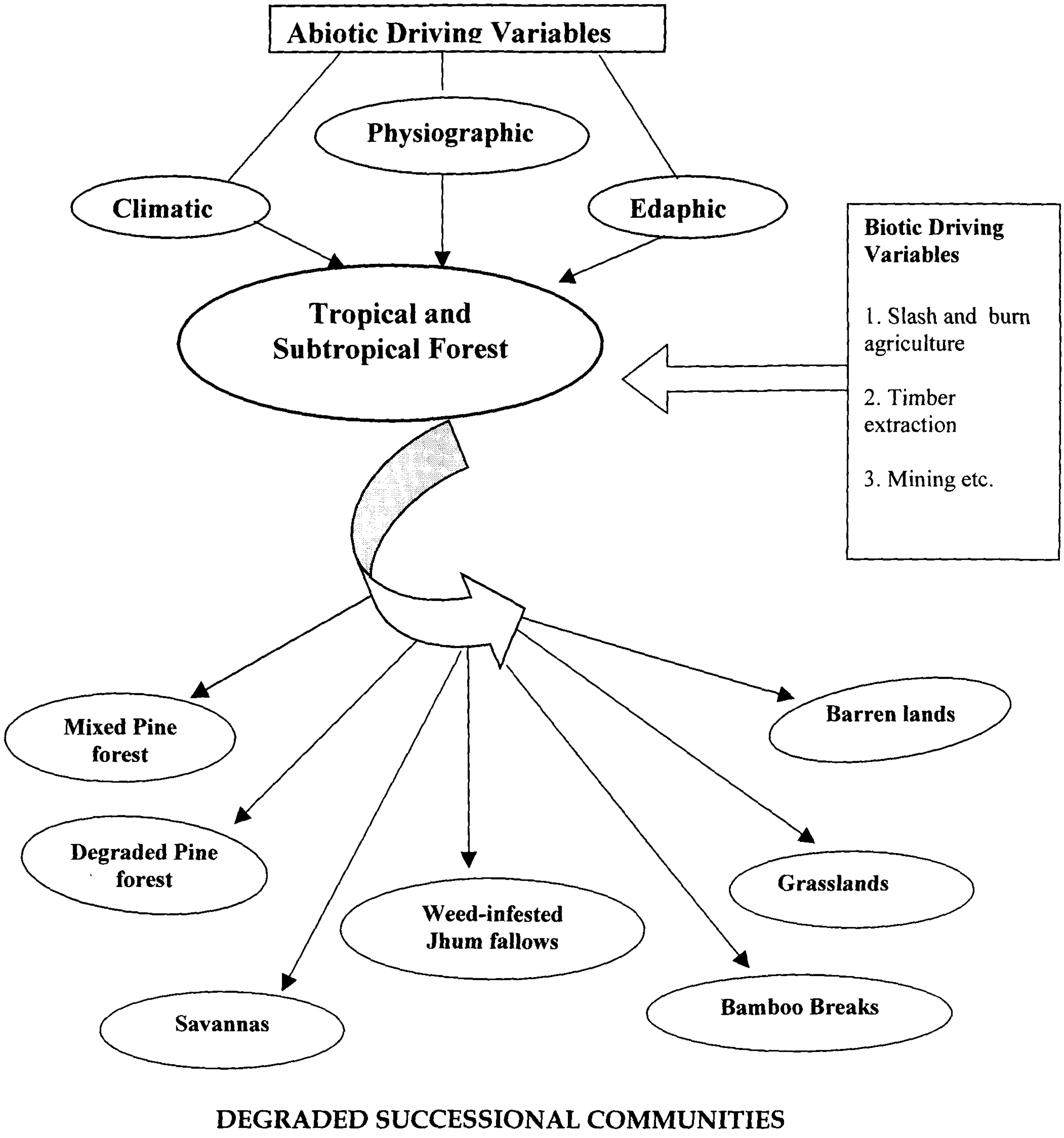


Fig. 4.2. Schematic representation of ecological factors responsible for development of forest and other plant communities in Meghalaya.

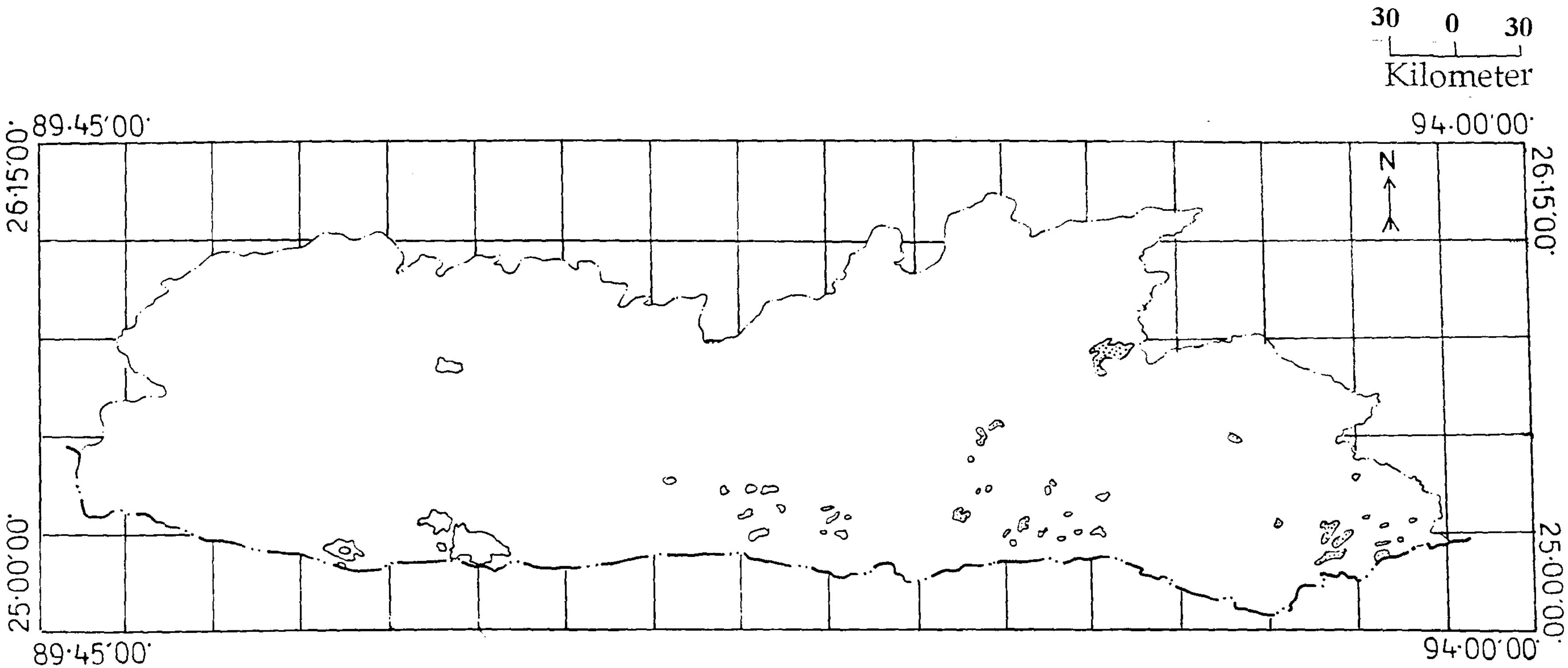
Tropical moist deciduous forest

This forest type is represented by sal-bearing forest at low elevation in Rongrengiri, Sangsuk, Darugiri and Baghmara areas of Garo hills where annual rainfall is less than 150 cm. The forest covers a small area of about 124.8 sq. km in the state and their distribution is shown in Map 4.3. Along with *Shorea robusta*, other tree species like *Tectona grandis, Terminalia myriocarpa, Sterculia villosa, Calliandra* sp., *Styrax serrulatum*, *Cordia grandis*, *Picrasma javanica*, *Embelia floribunda*, *Callicarpa arborea*, *Bauhinia variegata*, *Dysoxylum binectariferum*, *Lagerstroemia parviflora*, *Schima wallichii*, *Dillenia scabrella* and *Mallotus philippensis* are found in the forest. The under storey is composed of *Clerodendrum viscosum*, *Eupatorium adenophorum*, *Psychotria monticola*, *Melastoma malabathricum*, *Pongamia* sp., *Sabia purpurea*, *Ardisia neriifolia*, *Digitaria* sp., *Desmodium* sp., *Gleichenia* sp., and *Vandelia* sp.

Subtropical evergreen forest

It generally occurs above 1200 m asl where average annual rainfall ranges between 300 and 500 cm and temperature shows a noticeable difference between summer and winter season. The ground frost is common in December-January. Climatic data of Jowai (Jaintia hills) and Cherrapunji (East Khasi hills) where this forest type occurs are given in Chapter II (Fig. 2.1).

Soil moisture in the studied stands varied between 40% and 42%. The soil temperature was relatively low (11.8 ^{0}C) in stand EG-III than the other two stands. In all three stands soil was acidic with pH ranging between 5.17 and 5.80.



Map 4.3. Map showing area and distribution of different size patches under subtropical moist deciduous forests in the state of Meghalaya.

Soil organic carbon and organic matter ranged from 1.45 to 2.75% and from 2.5 to 4.74%, respectively. The soil in EG-III was rich in SOC and SOM than the other two stands. In all three stands concentration of SOC in the upper soil layer (0-10 cm) was more than the lower layer (10-30 cm). Total Kjeldahl nitrogen (%) ranged between 0.32% and 0.42% in stand EG-I, 0.29% and 0.44% in EG-II, and 0.17% and 0.26% in EG-III. Available phosphorus ($\mu g\ g^{-1}$) ranged between 23.3 and 28.7 in EG-I, 27.2 and 36.7 in EG-II, and 11.6 to 28.7 in EG-III (Table 4.1).

Table 4.1. Soil characteristics of evergreen forest.

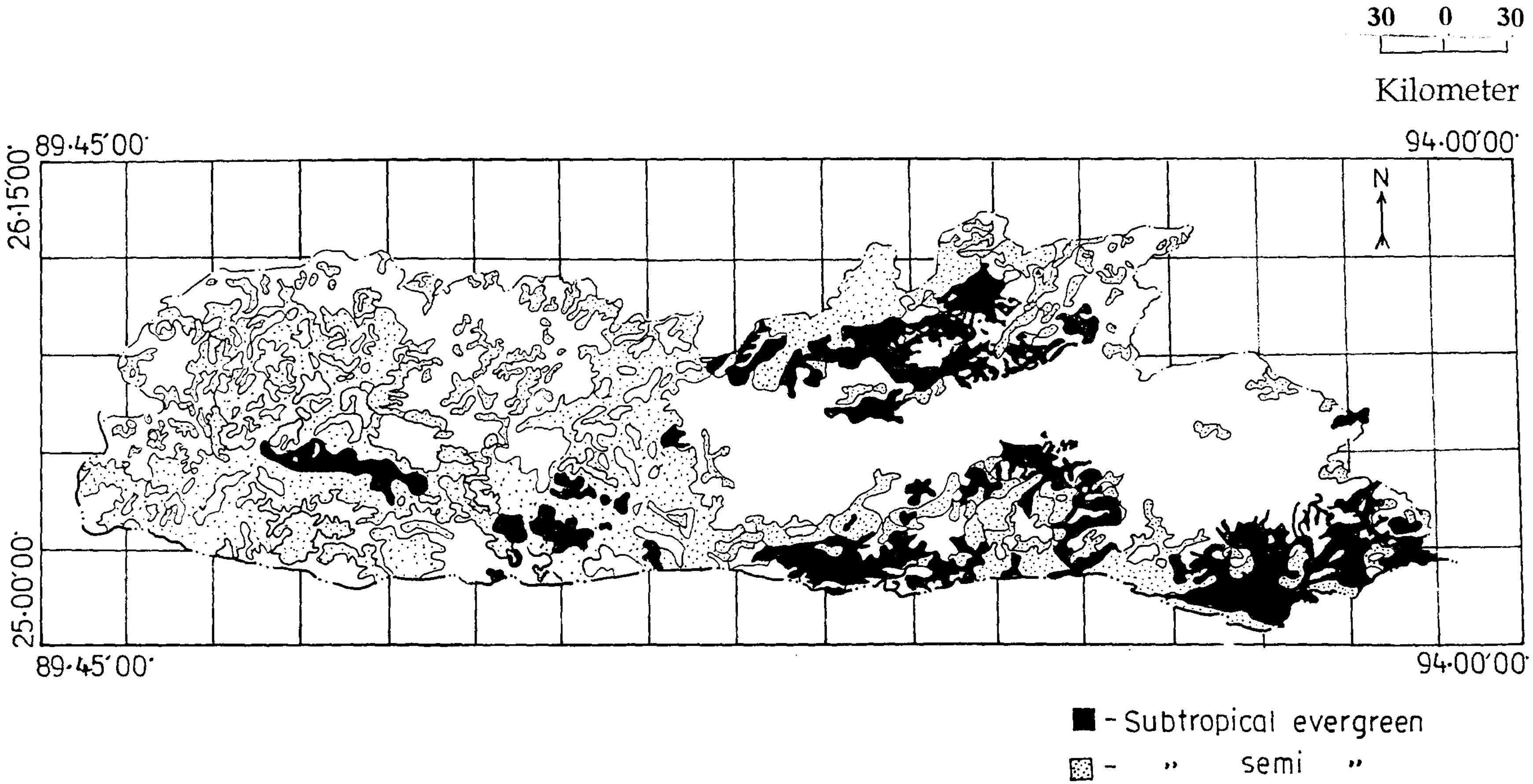
	EG-I			EG-II			EG-III		
	0-10cm	10-20cm	20-30cm	0-10cm	10-20cm	20-30cm	0-10cm	10-20cm	20-30cm
Physical characteristics									
Soil moisture (%)	31.8	32.3	35.2	33.1	36.7	40.5	41.9	40.9	40
Soil temperature (^{0}C)		20.7			21.2			11.8	
pH	5.80	5.41	5.24	5.72	5.64	5.32	5.49	5.19	5.17
Chemical characteristics									
Soil organic carbon (%)	2.62	1.84	1.45	2.47	2.17	2.06	2.75	2.2	1.68
Soil organic matter (%)	4.52	3.17	2.5	4.26	3.74	3.55	4.74	3.79	2.9
Total Kjeldahl nitrogen (%)	0.42	0.35	0.32	0.44	0.32	0.29	0.26	0.21	0.17
C/N ratio	6.55	5.26	4.53	5.61	6.78	7.1	10.58	10.48	9.88
Available phosphorus ($\mu g\ g^{-1}$)	28.7	25	23.3	36.7	31.6	27.2	24.9	14.6	11.6

The forest covered about 2547 sq. km in Jaintia hills (some parts of Narpuh and Saipung reserve forest), Khasi hills (Mawphlang and Cherrapunji areas), Ri bhoi (Langbi, Kariong, Umter, Mopon and Nogpydem areas), and Garo hills (upper reaches of Tura and Siju reserve forest) districts (Map 4.4).

The forest patches of varying sizes ranging from < 1 sq. km to 110 sq. km are found mainly on inaccessible hill slopes and valleys along the banks of rivers and streams, thereby restricting their degradation. Large continuous patches are rare. About 56% of 99 measured patches, were < 10 sq. km size. Five large patches (*ca.* 3% of the total number of patches measured) covered 41% (1163 sq. km) of the total area under this type of forest (Fig. 4.3).

The trees are generally short statured not exceeding >25 m height. Buttressed trunks and lianas are rare. Stratification is indistinct in the valleys, but it is clear at hilltops. The shrubby and herbaceous layers are clearly seen in the forest. Epiphytes, mosses and liverworts are abundant. The forest floor is spongy due to presence of thick litter and duff layers and a dense network of fine roots.

Tall scattered trees of *Castanopsis* sp., *Lithocarpus elegans, Engelhardtia spicata, Ficus elastica, Mangleitia insignis, Prunus nepalensis, Exbuklandia populnea* and *Betula* sp., constitute the canopy layer of the forest. Occasionally, *Schima wallichii* is also seen. *Viburnum foetidum, V. simonsii, Quercus glauca, Helicia nilagirica, Michelia punduana, Vernonia vulkamerifolia, Daphne involucrata, Symplocos racemosa* and *Ligustrum robustum* are common in the sub-canopy layer. Tree ferns are commonly found in the forest.



Map 4.4. Map showing area and distribution of different size patches under subtropical evergreen and semi-evergreen forests in the state of Meghalaya.

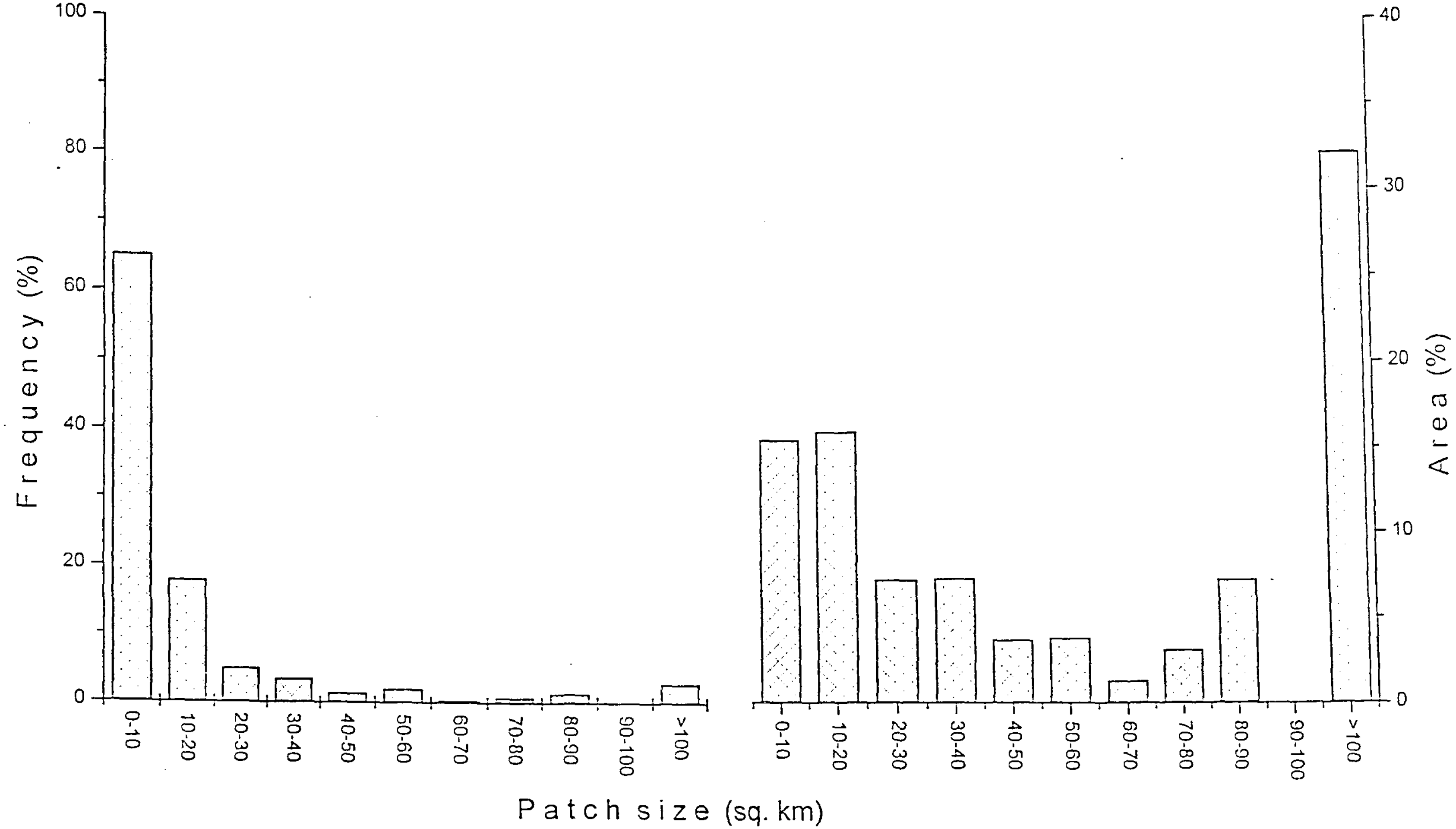


Fig. 4.3. Frequency distribution of patch size-classes and area covered by different patch-size classes of the evergreen forest in Meghalaya.

The common shrubby species found in the forest include *Ganinothalamus sesquiopedalis, Sarcococca saligna, Sarcandra glabra, Baliospermum micranthum, Neillia thorsiflora, Ixora subsessilis, Clerodendrum* sp., *Eurya japonica, Psychotria* sp,. *Ardisia* sp., *Camellia caudata, Saurauria* sp, and members of Acanthaceae and Araliaceae.

The forest floor is covered with mosses, selaginellas and angiospermous species such as *Begonia palmata, Senecio griffithii, Sonerilla* sp., *Impatiens* sp., *Didymocarpus punduana, Elatostema rupestre, Begonia rubro-venia, Disporum* sp., and members of Zingiberaceae, Araceae and Commelianaceae. *Clematis* sp., *Smilax* sp., *Dioscorea* sp., *Melodinus* sp. and species of Menispermaceae and Cucurbitaceae are the common climbers in the forest.

Subtropical semi-evergreen forest

The altitudinal limits of distribution and climatic conditions prevailing in the subtropical semi-evergreen forest area are similar to those of evergreen forest. A transitional zone between tropical and subtropical forests is distinguishable at certain places between 1000-1400 m.

The soil was thin, loamy sand. The soils of semi-evergreen forest were comparatively more acidic (pH ranges from 5 to 5.3), and contain less organic carbon (1.18 to 2.18%), organic matter (2.03 to 3.76%), total Kjeldahl nitrogen (0.18 to 0.28%), and available phosphorus (12.8 to 31.7 $\mu g\ g^{-1}$) than the evergreen forest sites. Concentrations of soil organic carbon, organic matter, total Kjeldahl nitrogen and available phosphorus were higher in upper layer of soil than the lower layer in both the stands (Table 4.2).

The subtropical evergreen forest is richer in species content than the evergreen forest. Presence of few deciduous species, which shed their leaves during the dry months between February and April, give semi-evergreen appearance to the forest. The number of deciduous trees, however, varies from site to site. Prickly and thorny species are commonly found in the forest.

Table 4.2. Soil characteristics of semi-evergreen forest.

	SEG-I			SEG-II		
	0-10cm	10-20cm	20-30cm	0-10cm	10-20cm	20-30cm
Physical characteristics						
Soil moisture (%)	34.1	37.2	38.9	29.5	30.2	31.6
Soil temperature (^{0}C)		13.8			21.6	
pH	5.3	5.1	5.1	5.12	5.1	5
Chemical characteristics						
Soil organic carbon (%)	2.18	1.64	1.31	1.9	1.45	1.18
Soil organic matter (%)	3.76	2.83	2.26	3.28	2.5	2.03
Total kjeldahl nitrogen (%)	0.27	0.19	0.18	0.28	0.22	0.18
C/N ratio	8.07	8.63	7.28	6.79	6.59	6.56
Available phosphorus ($\mu g\ g^{-1}$)	31.7	24.5	15.6	31.5	20.9	12.8

This type of forest is found on northeastern slopes of Jaintia hills (major areas of Narpuh and Saipung reserve forest), Ri bhoi (Mopon, Mayang, Umsaw and Nogkhyllum wildlife reserve forest), Khasi hills (Mawsynram, Ryungud and Mosing, and southern parts of the district) and Garo hills (Damalgiri, Rangira, Sembu and Nokatgiri areas) and covers about 4788 sq. km area of the state (Map 4.4). The forest is highly fragmented into small patches not exceeding 10 sq. km area and such patches are present in the large number (192 patches out of 295 patches) due to timber extraction and shifting. There are few (8) patches of larger size (>100 sq. km). They cover the maximum area (Fig. 4.4).

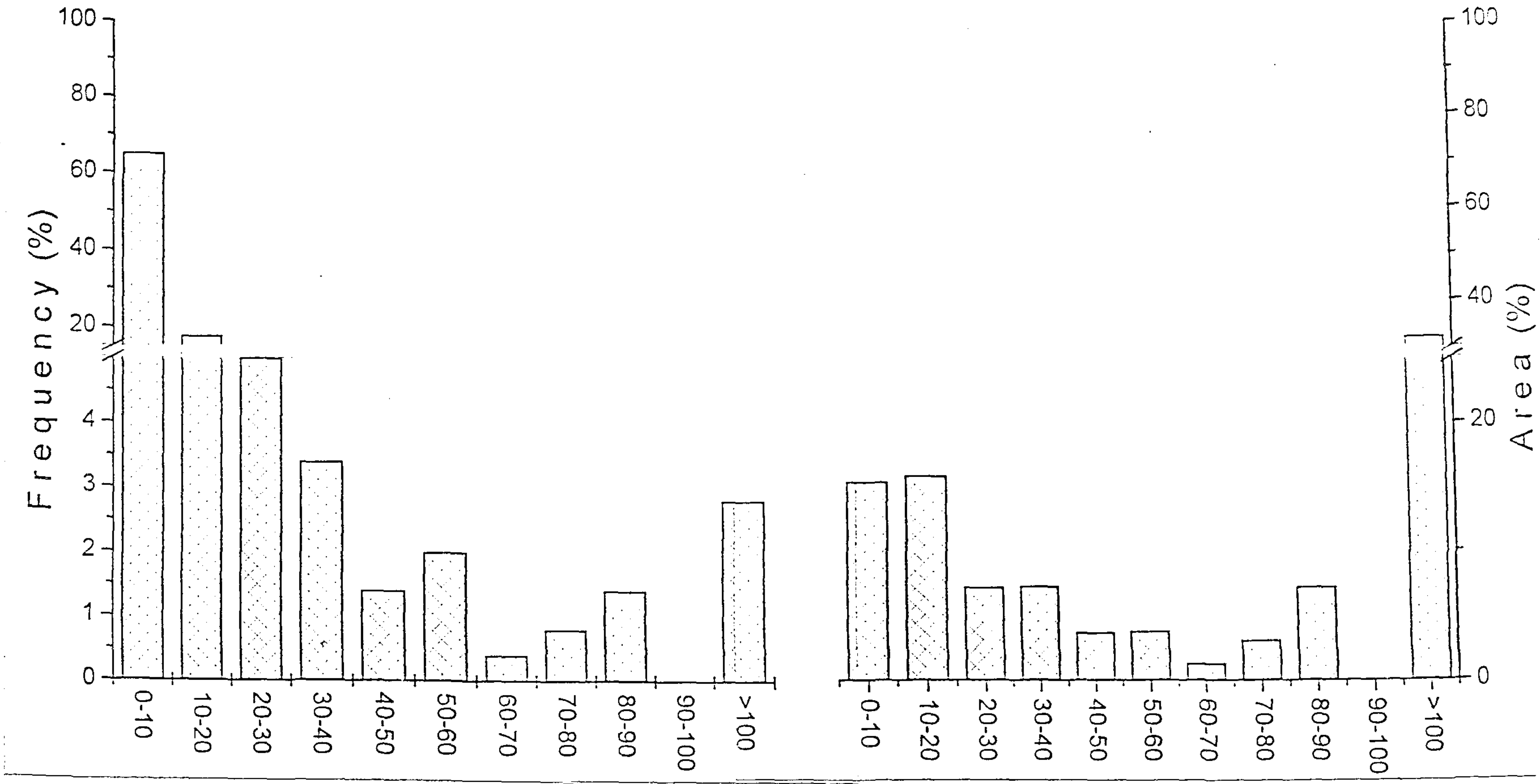


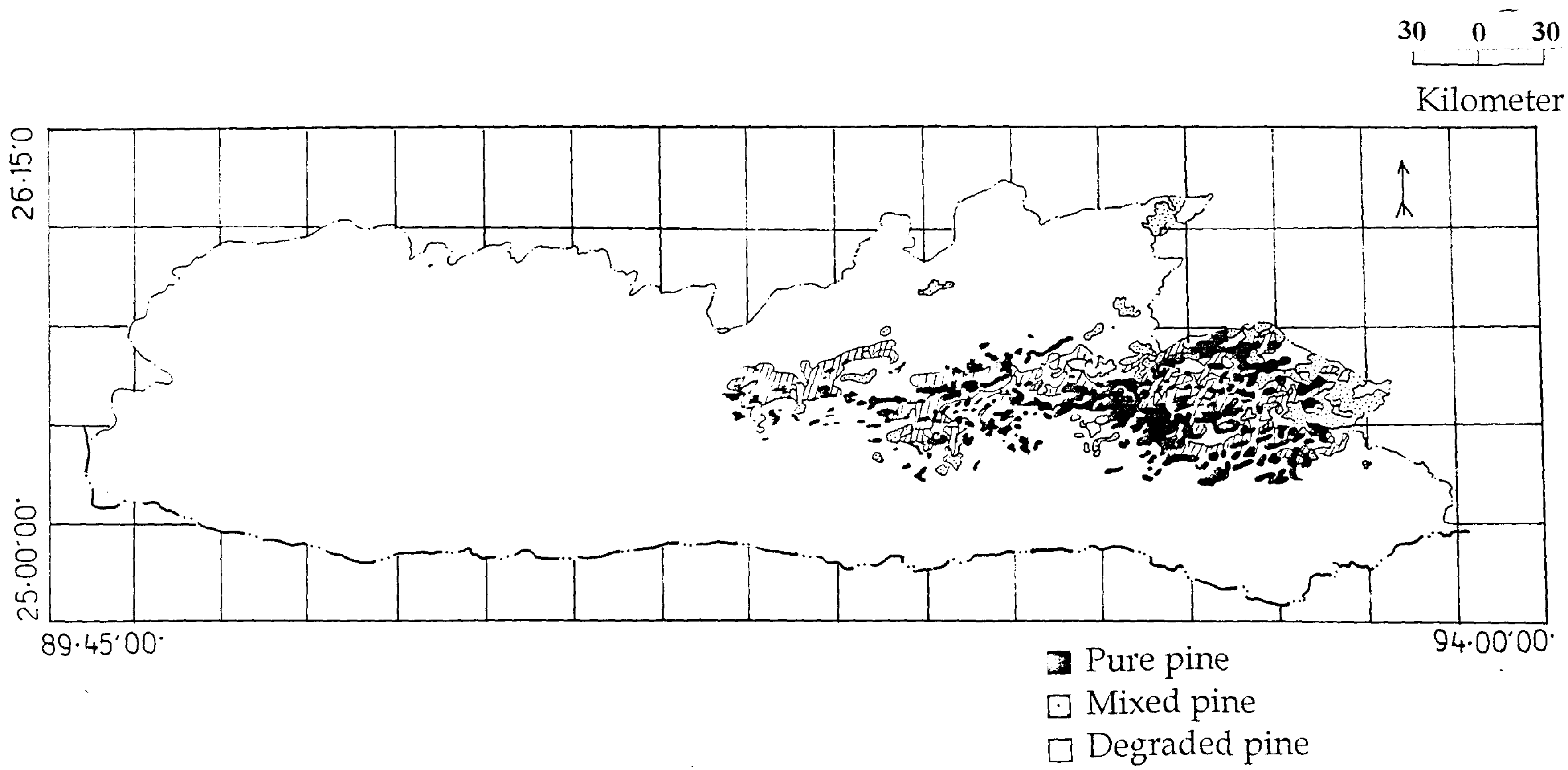
Fig.4.4. Frequency distribution of patch size-classes and area covered by different patch-size classes of the semi-evergreen forest in Meghalaya.

The common canopy (25 m height) species are *Engelhardtia spicata, Castanopsis indica*, *Sapindus rarak, Paramichelia baillionii, Elaeocarpus floribundus, Meliosma wallichii, Diospyros undulata, Ficus altissima* and *Vitex glabrata*. The sub-canopy in the forest is composed of small trees of *Vitex vestita, Quercus semicarpifolia, Casearia vareca, Micromelum integrimum, Photinia arguta, Symplocos cochinchinensis* and *Xylosma controversum.*

Lianas are less frequent and they are represented by *Mucuna macrocarpa, Tetrastigma obovatum* and *Celastrus campionii*. The shrub layer has fewer species. The common shrubs are *Crotalaria assamica, Boehmaria platyphylla, Capparis acutifolia, Lyonia ovalifolia, Randia griffithii, Mussaenda glabra, Desmodium* sp., *Maesa tetrandra* and *Clerodendrum* sp. The herbaceous layer is sparse. The common flowering plants of this layer are *Pilea umbrosa, Galinsoga parviflora, Anisadenia khasiana, Curcuma* sp., *Polygalla* sp., *Acanthus leucostachys, Pouzolzia hirta, Hedychium* sp., and many plants of Asteraceae. Mosses and ferns are rare.

Subtropical pine forest

The forest is confined to the central upland of Shillong plateau between *ca.*, 1000-2000 m asl. The climatic conditions are similar to those of evergreen and semi-evergreen forests. It occurs in Khasi and Jaintia hills above 800 m (either as pure or mixed stands) on nutrient-poor soil (Map 4.5). The forest is exposed to annual winter fire when ground vegetation is almost completely dry. Besides annual fire, other biotic disturbances such as fuelwood collection, timber extraction and grazing are common in the forest. As a result of these



Map 4.5. Map showing area and distribution of different size patches under subtropical pine forests in the state of Meghalaya.

activities, the forest has been fragmented into small patches. More than 90% patches are of less than 1 sq. km area. About 7% forest patches are in the range of 1-10 sq. km area. Large patches (>30 sq. km) are rare to find (Fig. 4.5). The area covered by this forest is about 1694 sq. km.

The pine forests occur on well drained, porous acidic (pH 4.65 to 5.12) soils with partially exposed to fully exposed rocks, primarily limestones (Loope and Dunevitz 1981). Soil development is minimal where recurrent fire has consumed litter and under-story vegetation. There is usually very little organic matter left on the surface, which sometimes is a bare rock. The underlying rocks are overlain with a thin layer of poor soil, which serves as the rooting medium for pine.

Soils of the pine stands had relatively low organic carbon (1.2 to 3.2%), organic matter (1.81 to 4.1%), total Kjeldahl nitrogen (0.11 to 0.17%) and available phosphorus (9.6 to 11.6 $\mu g\ g^{-1}$) than the soils of the semi-evergreen and evergreen forest stands. The concentration of all these constituents was higher in the upper soil layer than the lower layer (Table 4.3).

The average height of pine trees ranges between 20 and 35 m, however, on degraded sites the height may be less. Few scattered trees of broad-leaved species are often associated with pine. A few small trees or large shrubs are found scattered in the forest forming the sub-canopy layer. Annual fire prevents establishment of shrubs and other woody elements. However, weeds and perennial grasses form dense undergrowth during monsoon.

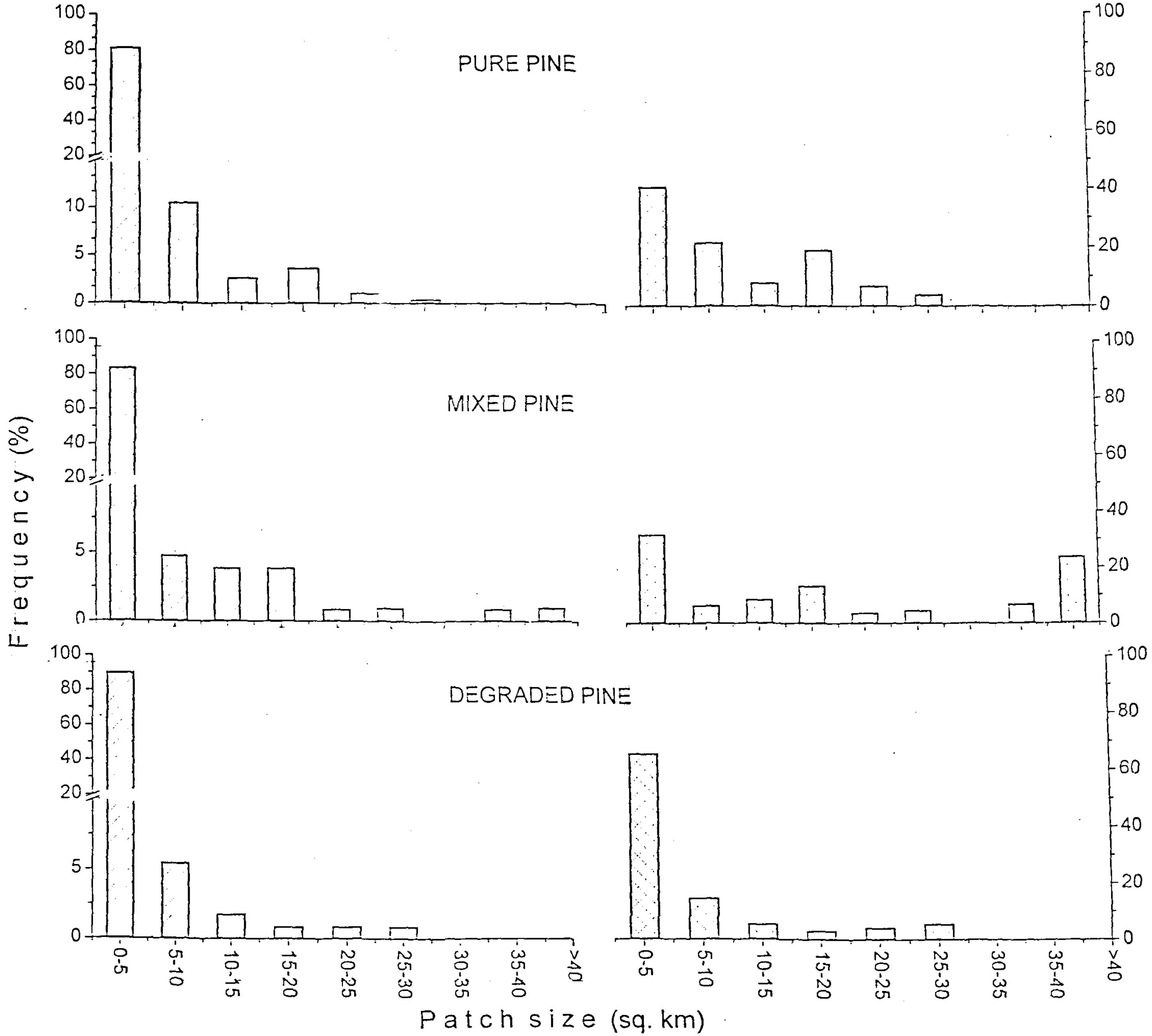


Fig.4.5. Frequency distribution of patch size-classes and area covered by different patch-size classes of the pine forest in Meghalaya.

Table 4.3. Soil characteristics of pine forest.

	P-I			P-II			P-III		
	0-10cm	10-20cm	20-30cm	0-10cm	10-20cm	20-30cm	0-10cm	10-20cm	20-30cm
Physical characteristics									
Soil moisture (%)	23.8	25.5	29.5	27.0	27.0	26.2	26.3	30.1	32.6
Soil temperature (^0C)		20.6			20.1			13.2	
Soil texture									
pH	4.97	4.78	4.66	4.88	4.68	4.65	5.1	5.12	5.0
Chemical characteristics									
Soil organic carbon (%)	1.59	1.35	1.05	2.33	1.94	1.38	2.38	1.60	1.35
Soil organic matter (%)	2.74	2.33	1.81	4.02	3.35	2.38	4.10	2.76	2.33
Total Kjeldahl nitrogen (%)	0.15	0.13	0.11	0.16	0.15	0.12	0.17	0.14	0.15
C/N ratio	10.6	10.4	9.6	11.1	12.9	11.5	14	11.4	9.0
Available phosphorus ($\mu g\ g^{-1}$)	17.2	12.6	10.3	17.9	11.7	8.9	17.2	15.1	10.4

Pine forest is very poor in tree species content. At places it forms a mixed stand with *Schima wallichii*, *Prunus undulata*, *Prunus cerasoides*, *Rhus javanica*, *Quercus dealbata*, *Q. glauca*, *Q. griffithii*, *Lyonia ovalifolia*, *Rhododendron arboreum*, *Alnus nepalensis* and *Exbucklandia populnea*. The shrubby undergrowth includes *Rubus ellipticus*, *R. khasianus*, *R. rugosus*, *Myrsine semiserrata*, *Osbeckia crinita*, *Desmodium* sp., *Eupatorium* sp., *Lantana camara*, *Bidens pilosa*.

Discussion

The tropical and subtropical broad-leaved forests found at lower and higher altitudes, respectively, represent the climax plant communities in the state. Shifting agriculture, logging, mining and other human activities have been responsible for fragmentation, destruction and degradation of these climax communities giving rise to large number of secondary successional communities, which are found on the degraded sites. High rainfall and hilly terrain have further accentuated the human impact on the forest.

The species composition and stability of these communities depend on site condition and biotic stress. The tropical and subtropical evergreen and semi-evergreen forests are very rich in plant diversity and harbour large number of rare and endemic species. Contrary to these forests, pine forests are poor in the species richness. They have developed as a stable disclimax community, on the disturbed subtropical broad-leaved forest sites under the influence of annual fire and other biotic disturbances.

The soil profile in broad-leaved forest is well developed, acidic and rich in organic matter and nutrients. On the contrary, the soil in the pine forest is more acidic and poor in organic matter and nutrients.

The state of Meghalaya, like other parts of northeast India, is undergoing rapid transformation due to urbanization, commissioning of hydroelectric projects, mining and extraction of forest products, besides continuance of age-old practice of shifting agriculture or 'Jhum'. All these activities are destroying natural forests. As a result, the forests are getting fragmented into small patches as is evident from the preponderance of small patches of both tropical and subtropical forests. All forest types in the state are highly disturbed. It is clearly evident from the high frequency of small-size forest patches. However, pine forests are most disturbed and very highly fragmented.

Fragmentation of the forest may have serious consequences on species composition, community structure and regeneration of trees in the forest communities of the state. Already there are reports that tree felling during the past few decades has degraded the forests (Tripathi *et al.* 1996) as a result of which a number of species have become rare (Tiwari *et al.* 1998, Jamir 2000) and few indigenous species such as *Cycas pectinata* and *Dipteris wallichi* reported from this area by Hooker (1854), have been eliminated due to inundation of large forest tract by hydroelectric reservoirs such as Brarapani lake (Kataki 1983).

CHAPTER V

Community Structure of Subtropical Evergreen Forest

The tropical and subtropical forests have attracted the attention of large number of workers all over the world, who have carried out comprehensive studies on their community organization and dynamics, and have estimated species richness, biomass, and productivity (Brunig 1983, Whitmore 1984, Valencia *et al.* 1994, Aiba and Kitayama 1999). Recent studies have emphasized their role as a major carbon sink (FAO 1997, Evans 2001) in the global carbon cycle.

In Asia, these forests occupy much forested area of India and dry areas of Southeast Asia, which have pronounced periodicity of temperature and dry and wet seasons. These forests are best developed in monsoon areas of India, Burma, Thailand and Malaya (Champion 1936, Puri 1960, Ogawa *et al.* 1961). The subtropical evergreen and semi-evergreen forests are very similar to each other. The major differences between the two are the occurrence of the latter mostly in the areas where the dry season is relatively longer and the presence of a greater proportion of deciduous tree species (about 30%) in their canopy as compared to evergreen forests.

The subtropical forests found in India have been termed as montane subtropical forests by Champion and Seth (1968). They have divided them into southern broad-leaved hill forests and northern wet hill forests because of considerable difference between the two. The latter are distributed up to 2000 m asl in eastern Himalaya and up to 1600 m asl on the hills south of Brahmaputra river where annual rainfall is generally over 2000 mm (Champion and Seth 1968). In these areas there is a noticeable difference between summer and winter temperature and the ground frost is common during December-January.

The subtropical forests found in northeast India are highly fragmented and disturbed by human activities. The undisturbed evergreen forest patches are mainly confined to inaccessible hill slopes and valleys along the banks of rivers and streams. The trees are generally shorter than those found in the semi-evergreen and lowland tropical rain forests. Buttressed trunks and lianas are rare. Stratification is indistinct in the valleys, but it is clear at higher elevation. Epiphytes, tree ferns, mosses and liverworts are abundantly found in the forest. Presence of thick litter and duff layers and a dense network of fine roots characterize the forest floor.

This chapter presents data on plant diversity, community structure, tree population structure and regeneration behaviour of ten dominant species in three stands of subtropical evergreen forest found between 1125 m and 2035 m asl in East Garo hills and East Khasi hills districts of the state of Meghalaya.

Plant diversity

Altogether, 176 species belonging to 132 genera and 76 families in stand EG-I, 159 species belonging to 123 genera and 72 families in stand EG-II, and 171 species belonging to 121 genera and 57 families in stand EG-III, were recorded from the three stands of evergreen forest. There were tropical, temperate, and Sino-Himalayan, Burma-Malaysian and Malayan elements in the forest. Besides, taxa belonging to primitive families like Annonaceae, Ranunculaceae, Piperaceae, Menispermaceae, Lauraceae and Myricaceae and primitive genera like *Sarcandra* and *Myrica* were also present in the forest. The Stand EG - I had the highest number of species, followed by stand EG - III and EG - II. The proportion of tree species was 56%, 54% and 55%, while that of the shrub species was 22%, 19% and 18% in the stands EG-I, EG-II and EG-III, respectively. The contribution of herbaceous species to total species richness was 22% in EG–I and 27% in EG–II and III.

From 1.2 ha area a total of 82 tree (> 15 cm cbh) species representing 63 genera and 36 families were recorded from EG-I stand, 93 species belonging to 65 genera and 38 families were recorded from EG-II, and 76 species representing 60 genera and 33 families were recorded from EG-III stand. The trees were distributed in three distinct strata. Canopy layer was composed of 11, 15 and 8 species in EG–I, II and III, respectively. Sub-canopy and treelet layers together had the maximum species in all the three stands. They together had 81% to 88% of the total tree species in the forest. *Elaeocarpus rugosus*, *Castanopsis tribuloides*, *Engelhardtia spicata* and *Duabanga grandiflora* were dominant canopy trees in EG-I (Table 5.1a), *Celtis tetranda*, *Duabanga grandiflora, Syzygium tetragonum* and *Dysoxylum gobara* in EG–II (Table 5.2a), and *Dysoxylum binectariferum*, *Echinocarpus murex, Elaeocarpus rugosus* and *Engelhardtia spicata* in EG–III stand (Table 5.3a).

Table 5.1a. Density (individuals ha^{-1}), basal cover (m^2 ha^{-1}), importance value index and distribution pattern of tree species (>15cm cbh) in stand I of the evergreen forest (EG).

Name of species	Family	Density	Basal cover	IVI	*Distribution pattern
Canopy trees (>20m height)					
Castanopsis tribuloides (Sm.) DC.	Fagaceae	28	1.13	9.5	Re
Duabanga grandiflora (Roxb. ex DC.) Walp.	Sonneratiaceae	4	0.15	1	C
Dysoxylum gobara (Buch.-Ham.) Merr.	Meliaceae	10	0.18	2.2	C
Elaeocarpus floribundus Bl.	Elaeocarpaceae	10	0.41	3.5	Ra
Elaeocarpus rugosus Roxb.	Elaeocarpaceae	17	0.08	3.7	Ra
Engelhardtia spicata (Wall.) Kds. & Val.	Juglandaceae	27	1.1	8.6	Ra
Mesua ferrea Linn.	Clusiaceae	19	0.57	5.7	Ra
Randia cochinchinensis (Lour.) Merr.	Rubiaceae	7	0.18	2.2	Ra
Sapium baccatum Roxb.	Euphorbiaceae	14	0.24	3.7	Ra
Schima wallichii (DC.) Korth.	Theaceae	15	0.42	4.7	Ra
Syzigium cumini (Linn.) Skeels	Myrtaceae	10	0.15	2.2	C
Sub-canopy trees (10-20m height)					
Adinandra griffithii Dyer.	Theaceae	18	0.41	4.7	Ra
Aesculus assamica Griff.	Sapindaceae	10	0.16	2.5	C
Aphania rubra (Roxb.)	Sapindaceae	10	0.67	4.1	C
Aquilaria agallocha Roxb.	Thymeliaeaceae	13	1.53	7	C
Ardisia floribunda Wall.	Myrsinaceae	26	1.1	6.8	C
Beilshmiedia assamica Meissn.	Lauraceae	3	0.6	2.4	C
Bridelia retusa (Linn.) Spreng.	Euphorbiaceae	27	0.76	7.6	Ra
Callicarpa arborea Roxb.	Verbenaceae	20	1.93	10.1	Ra
Callicarpa vestita Wall. ex Cl.	Verbenaceae	38	1.41	12	Re
Calophyllum polyanthum Choisy	Clusiaceae	15	0.24	4	Ra
Caryota urens Linn.	Arecaceae	7	0.15	1.8	C
Casearia zeylanica (Gaert.) Thw.	Flacourtiaceae	6	0.07	1.6	C
Castanopsis indica A. DC.	Fagaceae	32	1.91	12.7	Re
Castanopsis purpurella (Miq.) Balak.	Fagaceae	21	0.31	6.1	Re
Drimycarpus racemosus (Roxb.) Hk.f.	Anacardiaceae	7	0.32	2	C
Drypetes asamica (Hk. f.) Pax. et Hoffm.	Euphorbiaceae	8	0.08	1.7	C
Elaeocarpus acuminatus Wall. ex Mast.	Elaeocarpaceae	10	0.17	2.5	C
Ficus nervosa Heyne. ex Roth	Moraceae	23	1.25	6.8	C
Garcinia cowa Roxb.ex DC.	Clusiaceae	13	0.27	3.9	Ra
Garcinia pedunculata G. Don.	Clusiaceae	10	0.28	3.1	Ra
Lindera latifolia Hk. f.	Lauraceae	14	0.57	4.8	Ra
Litsea cubeba (Lour.) Pers.	Lauraceae	4	0.09	1.2	C
Litsea laeta (Nees) Hook. f.	Lauraceae	12	0.21	3	C
Macaranga indica Wt.	Euphorbiaceae	19	2.09	10.7	Re
Macropanax undulatus (Wall.ex G. Don) Seem	Araliaceae	9	0.38	3.3	Ra
Mallotus philippensis (Lam.) Muell.-Arg.	Euphorbiaceae	10	0.41	3.4	C
Micromelum integerrimum (Roxb.) Wt. & Arn.	Rutaceae	3	0.11	0.7	C
Myrica esculenta Buch.-Ham. ex D. Don	Myricaceae	7	0.17	1.9	C

Neolitsea cassia (Linn.) Kosterm.	Lauraceae	10	0.14	2.5	C
Ostodes paniculata Bl.	Euphorbiaceae	14	0.48	4.7	Ra
Persea gamblei (King. ex Hk. f.) Kosterm	Lauraceae	23	1.09	7.3	Ra
Polyalthia simiarum (Hk. f. & Th.) Hk. f. & Th.	Annonaceae	8	0.13	2.1	C
Prunus nepalensis (Ser.) Steud.	Rosaceae	15	0.36	4.7	Re
Saprosma ternatum Hk. f.	Rubiaceae	27	0.22	6.4	Re
Sarcosperma arboreum Cl.	Sapotaceae	10	0.05	3.7	Re
Sarcosperma griffithii Cl.	Sapotaceae	3	0.1	1	C
Sterculia hamiltonii (O. ktze.) Adelb.	Sterculiaceae	23	0.19	5.5	Re
Syzygium sp.	Myrtaceae	7	0.25	2.4	Ra
Syzygium tetragonum (Wt.) Kurz	Myrtaceae	6	0.15	1.6	C
Turpinia pomifera (Roxb.) DC.	Sapindaceae	4	0.07	1	C
Treelet (2-10m height) layer					
Ardisia virens Kurz.	Myrsinaceae	7	0.33	2.4	C
Beilshmiedia roxburghiana Nees.	Lauraceae	7	0.18	1.9	C
Boehmeria macrophylla D. Don.	Urticaceae	8	0.04	1.8	C
Capparis acutifolia Sm.	Capparidaceae	4	0.04	0.8	C
Cinnamomum pauciflorum Nees.	Lauraceae	11	0.07	2.5	Ra
Citrus hystrix DC.	Rutaceae	30	0.8	9.2	Re
Desmos chinensis Lour.	Annonaceae	12	0.33	3.4	C
Diospyros kaki Thunb.	Ebenaceae	3	0.06	0.6	C
Diospyros toposia Ham.	Ebenaceae	4	0.05	1.1	C
Euonymus lawsonii Cl. & Pr.	Celastraceae	10	0.17	2.6	C
Eurya acuminata DC.	Theaceae	4	0.11	1.2	C
Ficus hirta Vahl.	Moraceae	17	0.81	5.8	Ra
Garcinia lancifolia (G. Don.) Roxb.	Clusiaceae	26	0.36	6.7	Re
Glochidion assamicum Hk. f.	Euphorbiaceae	3	0.06	0.8	C
Helicia excelsa Bl.	Proteaceae	19	0.41	4	C
Helicia nilagirica Bedd.	Proteaceae	10	0.28	2.5	C
Litsea lancifolia (Roxb. ex Nees.) Wall. ex Hk. f.	Lauraceae	11	0.33	3.2	C
Litsea salicifolia (Roxb. ex Nees.) Hk. f.	Lauraceae	13	0.38	4.1	Ra
Maesa indica (Roxb.) Wall.	Myrsinaceae	13	0.8	5.3	Ra
Oriocnide integrifolia (Gaud.) Miq.	Urticaceae	2	0.03	0.5	C
Phoebe lanceolata (Nees.) Nees	Lauraceae	15	0.32	4.6	Re
Photinia notoniana Wt. & Arn.	Rosaceae	12	0.14	3.1	Ra
Prunus undulata Buch.-Ham. ex D. Don Prodr.	Rosaceae	11	0.4	3.8	Ra
Psychotria symplocifolia Kurz.	Rubiaceae	10	0.23	3.1	Ra
Saurauia nepaulensis DC.	Saurauiaceae	4	0.08	1.2	C
Taxus baccata Linn.	Taxaceae	18	0.21	2.6	C
Trevesia palmata (Roxb.) Vis.	Araliaceae	2	0.02	0.4	C
Vernonia volkameriifolia DC.	Asteraceae	6	0.11	1.6	C
Viburnum coriaceum Bl.	Caprifoliaceae	11	0.23	3	Ra
Large climbers					
Fissistigma verrucosum (Hk. f. & Th.) Merr.	Annonaceae	10	0.46	3.5	C
Lasianthus hookeri Cl. ex Hk. f.	Rubiaceae	2	0.01	0.3	C
		1023	**33.3**	**300**	

*Re=regular, Ra=random, C=contagious distribution pattern.

Table 5.2a. Density (individuals ha^{-1}), basal cover (m^2 ha^{-1}), importance value index and distribution of tree species in stand II of the evergreen forest (EG).

Name of species	Family	Density	Basal cover	IVI	*Distribution pattern
Canopy trees (>20m height)					
Albizia chinensis (Osb.) Merr.	Mimosaceae	14	0.782	4.7	C
Casearia kurzii Cl.	Flacourtiaceae	16	0.6	6	Ra
Celtis tetrandra Roxb.	Ulmaceae	10	0.367	2.7	C
Diospyros undulata DC.	Ebenaceae	3	0.07	0.9	C
Duabanga grandiflora (Roxb. ex DC.) Walp.	Sonneratiaceae	6	0.535	2.7	C
*Dysoxylum alliarium (*Ham.) Balak	Meliaceae	4	0.07	2.8	Re
Dysoxylum binectariferum Hk. f. et Bedd.	Meliaceae	13	0.506	4.7	C
Dysoxylum gobara (Buch.-Ham.) Merr.	Meliaceae	18	1.385	8.4	Ra
Paramichelia baillonii Pierre.	Magnoliaceae	2	0.115	0.7	C
Syzyzium cumini (Linn.) Skeels.	Myrtaceae	15	0.317	5.7	Re
Syzyzium tetragonum Wall.	Myrtaceae	3	0.138	1	C
Talauma hodgsonii Hk. f. & Th.	Magnoliaceae	4	0.414	2.1	C
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	7	0.872	3.1	C
Terminalia citrina (Gaertn.) Flem.	Combretaceae	3	0.236	1.6	C
Tetrameles nudiflora R. Br.	Tetrameliaceae	11	0.63	4.2	C
Sub-canopy trees (10-20m height)					
Acacia pruinensis Kurz.	Mimosaceae	14	0.239	3.1	C
Aporusa oblonga Muell.-Arg.	Euphorbiaceae	8	0.867	3.7	C
Bielshmiedia assamica Meissn.	Lauraceae	3	0.236	1.1	C
Callicarpa rubella Lindl.	Verbenaceae	3	0.127	1	C
Calophyllum polyanthum Choisy	Euphorbiaceae	13	0.429	3.4	C
Carallia brachiata (Lour.) Merr.	Myrtaceae	2	0.028	0.7	C
Caryota urens Linn.	Arecaceae	14	0.572	3.2	C
Castanopsis indica A. DC.	Fagaceae	13	3.251	9.7	C
Castanopsis kurzii (Hance.) Biswas	Fagaceae	58	7.629	28.9	Ra
Castanopsis purpurella (Miq.) Balak.	Fagaceae	9	1.368	5.6	C
*Cleidion spiciflorum (*Burm.) Merr.	Euphorbiaceae	18	0.582	4.9	C
Derris robusta (Roxb ex DC.) Benth.	Fabaceae	23	0.327	5.2	C
Dimocarpus longan Lour.	Sapindaceae	10	0.379	2.7	C
Diospyros stricta Roxb.	Ebenaceae	15	0.872	7.4	Re
Echinocarpus murex Benth.	Elaeocarpaceae	8	0.158	3.2	Ra
Elaeocarpus lancifolius Roxb.	Elaeocarpaceae	25	2.247	11.4	Ra
Ficus elastica Roxb. ex Horneum.	Moraceae	18	2.119	8.1	C
Ficus oligodon Miq.	Moraceae	4	0.33	1.4	C
Garcinia cowa Roxb. ex DC.	Clusiaceae	3	0.042	1.5	Ra
*Garcinia paniculata (*G. Don.) Roxb.	Clusiaceae	1	0.022	0.6	C
Glochidion acuminatum Muell.-Arg.	Euphorbiaceae	8	0.209	3.3	Ra
Ilex venulosa Hk.f.	Aquifoliaceae	2	0.037	0.7	C
Kydia calycina Roxb.	Malvaceae	16	1.453	5.7	C
Lindera caudata Benth.	Lauraceae	2	0.045	0.7	C
*Litsea laeta (*Nees.) Hook. f.	Lauraceae	8	0.233	1.9	C

Ficus nervosa Heyne. ex Roth.	Moraceae	10	0.07	2.1	Ra
Garcinia cowa Roxb.ex DC.	Clusiaceae	3	0.1	0.8	C
Helicia excelsa Bl.	Proteaceae	4	0.05	0.9	C
Helicia nilagirica Bedd.	Proteaceae	7	0.03	0.9	C
Kydia calycina Roxb.	Malvaceae	10	0.05	1.6	C
Litsea khasyana Meissn.	Lauraceae	27	0.14	4.4	Ra
*Litsea laeta (*Nees.) Hook. f.	Lauraceae	10	0.04	1.7	C
Macropanax undulatus (Wall.ex D.Don) Seem.	Araliaceae	10	0.08	1.8	C
Myrica esculenta Buch-Ham ex D.Don	Myricaceae	4	0.04	0.8	C
Olea dentata Wall.ex DC.	Oleaceae	19	0.08	2.2	C
Persea duthiei King ex Hk.f.	Lauraceae	7	0.36	2.3	C
Persea odoratissima Nees.	Lauraceae	17	0.1	2.8	Ra
Photinia polycarpa (Hk.f.) Balakr.	Rosaceae	10	0.07	1.4	C
Picrasma javanica Bl.	Simaroubaceae	27	0.17	4.3	Ra
Rhododendron arboreum Smith.	Ericaceae	4	0.02	0.8	C
Rhus javanica Linn.	Anacardiaceae	233	4.1	32.5	C
Schefflera hypoleuca Kurz.	Araliaceae	8	0.08	1.4	C
Spondias pinnata (Linn.f) Kurze.	Anacardiaceae	19	0.12	2.9	C
Treelet layer (2-10m height)					
Cleyera grandiflora Hk. f. & Th. ex Dyer	Theaceae	3	0.6	2.7	C
Antidesma acidum Reitz.	Euphorbiaceae	14	0.09	2.5	Ra
Aporusa dioica Roxb.	Euphorbiaceae	10	0.06	1.7	C
Beilshmiedia roxburghiana Nees.	Lauraceae	45	3.03	16.7	Ra
Berberis wallichiana DC.	Berberidaceae	21	0.88	6	C
Camellia caduca Brandis	Theaceae	33	0.2	3.6	C
Casearia vareca Roxb.	Flacourtiaceae	23	0.14	3.4	Ra
Cinnamomum pauciflorum Nees	Lauraceae	9	0.39	2.8	C
Coffea khasiana Hk.f.	Rubiaceae	32	1.34	8.7	C
Erythroxylum kunthianum King.	Erythroxylaceae	20	0.24	3.4	C
Euonymus attenuatus Laws.	Celastraceae	26	0.36	5.5	Re
Euonymus lawsonii Cl. & Pr.	Celastraceae	11	0.07	2	Ra
Eurya acuminata DC.	Theaceae	53	0.31	7.1	Ra
Eurya japonica Thunb.	Theaceae	57	0.28	6.2	C
*Garcinia lancifolia (*D. Don.) Roxb.	Clusiaceae	3	0.01	0.3	C
Gaultheria fragrantissima Wall.	Ericaceae	7	0.18	1.9	Ra
Ilex embelioides Hk.f.	Aquifoliaceae	4	0.02	0.4	C
Ilex odorata D.Don.	Aquifoliaceae	10	0.06	1.4	C
Ixora undulata Roxb.	Rubiaceae	52	0.42	7.3	Ra
Leptodermis griffithii Hk.f	Rubiaceae	10	0.05	3	Re
Leucosceptrum canum Smith	Lamiaceae	10	0.78	4.6	Ra
Litsea salicifolia (Roxb.ex Nees.) Hk.f.	Lauraceae	4	0.05	0.8	C
Mussaenda roxburghii Hk.f.	Rubiaceae	3	0.03	0.7	C
Neolitsea cassia Linn.	Lauraceae	43	0.35	7.1	Re
Olax acuminata Wall.	Oleaceae	3	0.06	0.6	C
Phyllanthus glaucus Wall.	Euphorbiaceae	4	0.03	0.8	C
Psychotria symplocifolia Kurz.	Rubiaceae	3	0.02	0.5	C
Pteracanthus griffithianus Nees.	Acanthaceae	9	0.38	3	Ra

Vatica lanceaefolia Bl.	Sapindaceae	16	1.119	5.4	C
Viburnum odoratissimum Ker.	Caprifoliaceae	3	0.044	0.8	C
Viburnum simonsii Hk. f. & Th.	Caprifoliaceae	2	0.043	0.7	C
Zizyphus mauritiana Lamk.	Rhamnaceae	2	0.043	0.5	C
Zizyphus rugosa Lamk.	Rhamnaceae	3	0.107	1.3	C
Large climbers					
Achronychia pedunculata (Linn.) Miq.	Rutaceae	10	0.367	2.9	C
Celastrus panuculatus Wall.	Celastraceae	4	0.112	1.4	C
		834	**38.8**	**300**	

*Re=regular, Ra=random, C=contagious distribution pattern.

Table 5.3a. Density (individuals ha^{-1}), basal cover (m^2 ha^{-1}), importance value index and distribution pattern of tree species in stand III of the evergreen forest (EG).

Name of species	Family	Density	Basal cover	IVI	*Distribution pattern
Canopy trees (>20m height)					
Cryptocarya andersonii King ex Hk. f.	Lauraceae	8	0.04	1.4	C
Dysoxylum binectariferum Hk. f. et. Bedd.	Meliaceae	27	0.43	4.7	C
Echinocarpus dasycarpus Benth.	Elaeocarpaceae	7	0.38	2.4	C
Echinocarpus murex Benth.	Elaeocarpaceae	13	0.13	2.1	C
Elaeocarpus rugosus Roxb.	Elaeocarpaceae	15	0.11	2.7	Ra
Engelhardtia spicata Leschen. ex Bl.	Juglandaceae	21	0.31	5.1	Re
Schima wallichii (DC.) Korth.	Theaceae	11	0.14	2.2	C
Vitex altissima Linn.	Verbenaceae	53	0.36	7.1	Ra
Sub-canopy trees (10-20m height)					
Aporusa oblonga Muell. Arg.	Euphorbiaceae	30	0.67	6.8	Re
Aporusa wallichii Hk. f.	Euphorbiaceae	10	0.16	2	C
Carpinus viminea Lindl.	Corylaceae	13	1.53	7.4	C
Cinnamomum tamala Fr. Nees	Lauraceae	23	0.21	3.6	C
Cleidion spiciflorum (Burm.) Merr.	Euphorbiaceae	7	0.03	1.1	C
Daphniphyllum himalayense (Benth.) Muell.-Arg.	Daphniphyllaceae	3	0.32	1.5	C
Diospyros pilosula (DC.) Hiern.	Ebenaceae	53	0.58	7.1	C
Drypetes assamica Hk. f.	Euphorbiaceae	27	0.76	6.7	Ra
Elaeocarpus sikkimensis Mast.	Elaeocarpaceae	6	0.07	1.4	C
Eriobotrya dubia Decne.	Rosaceae	28	1.14	7.6	Ra
Exbucklandia populnea (R. Br.ex Griff.) R.W. Br.	Hamamelidaceae	11	0.05	1.7	C
Ficus elastica Roxb.	Moraceae	178	0.96	17.3	C

Macaranga denticulata (Bl.) Muell.-Arg.	Euphorbiaceae	18	0.664	4	C
Macropanax undulatus (Wall. ex D. Don.) Seem.	Araliaceae	12	0.313	4	C
Mallotus philippensis (Lam.) Muell.-Arg.	Euphorbiaceae	14	0.312	3.7	C
Micromelum integerrimum (Roxb.) Roem	Rutaceae	3	0.189	0.9	C
Persea duthiei King. ex Hk. f.	Lauraceae	25	0.671	7.1	C
Persea odoratissima Nees.	Lauraceae	5	0.115	1.7	C
Picrasma javanica Bl.	Simaroubaceae	4	0.092	1.1	C
Premna bengalensis Cl.	Verbenaceae	3	0.089	1.2	C
Randia cochinchinensis (Lour.) Merr.	Rubiaceae	6	0.151	1.9	C
Randia wallichii Hk. f.	Rubiaceae	4	0.242	1.5	C
Saprosma ternatum Hk. f.	Rubiaceae	4	0.074	1.1	C
Symplocos lucida Thunb.	Symplocaceae	5	0.161	1.6	C
Symplocos racemosa Roxb.	Symplocaceae	6	0.322	2.1	C
Treelet layer (2-10m height)					
Antidesma acidum Reitz.	Euphorbiaceae	8	0.268	3.5	Ra
Antidesma acuminatum Wall.	Euphorbiaceae	14	0.608	6.7	Re
Aporusa aurea Hk. f.	Euphorbiaceae	2	0.144	0.7	C
Aporusa dioica (Roxb.) Muell.-Arg.	Euphorbiaceae	5	0.404	2.8	Ra
Aralia thomsonii Seem.	Araliaceae	7	0.172	1.8	C
Baccaurea ramiflora Lour.	Euphorbiaceae	11	0.63	3.1	C
Camellia caudata Wall.	Theaceae	13	0.358	4.3	C
Camellia cauduca Brandis	Theaceae	11	0.325	3.3	C
Citrus hystrix DC.	Rutaceae	6	0.151	1.5	C
Citrus medica Linn.	Rutaceae	17	0.414	3.6	C
Daphne involucrata Wall.	Thymeliaceae	7	0.172	2.7	Ra
Euonymus attenuatus Laws.	Celastraceae	7	0.141	2	C
Ficus elmeri Merr.	Moraceae	3	0.194	1	C
Ficus nervosa Heyne. ex Roth.	Moraceae	7	0.471	3.1	C
Glochidion assamicum Hk. f.	Euphorbiaceae	3	0.07	1	C
Glycosmis arborea (Roxb.) DC.	Rutaceae	9	0.202	3.9	Ra
Litsea salicifolia (Roxb.ex Nees.) Hk.f.	Lauraceae	14	0.38	2.8	C
Maesa indica (Roxb.) Wall.	Myrsinaceae	14	0.888	4.5	C
Oriocnide frutescens Thunb.	Urticaceae	1	0.026	0.4	C
Oriocnide integrifolia (Gaud.) Miq.	Urticaceae	4	0.179	1.5	C
Pandanus odoratissima Linn.	Pandanaceae	19	0.681	4.3	C
Psychotria denticulata Wall.	Rubiaceae	4	0.074	1.1	C
Psychotria erratica Hk. f.	Rubiaceae	20	0.783	6.7	Ra
Rhus acuminata DC.	Anacardiaceae	3	0.165	1.4	C
Rhus javanica Linn.	Anacardiaceae	14	0.537	5.7	Ra
Saurauia nepaulensis DC.	Saurauiaceae	2	0.035	0.5	C
Saurauia roxburghii Wall.	Saurauiaceae	1	0.021	0.4	C
Skimmia laureola (DC.) Sieb. & Zucc. ex Walp.	Rutaceae	3	0.08	0.7	C
Sterculia hamiltonii (O.) Ktze.	Sterculiaceae	2	0.121	0.7	C
Sterculia roxburghii Wall.	Sterculiaceae	1	0.046	0.4	C
Symplocos paniculata Thunb.	Symplocaceae	20	1.381	8.2	Ra
Syzyzium formosum Wall.	Myrtaceae	4	0.206	1.6	C

Saprosma ternatum Hf.f.	Rubiaceae	102	0.88	12.6	Ra
Sorbus microphylla Decaisne	Rosaceae	13	0.67	4.7	Ra
Symplocos laurina (Reitz.) Wall.	Symplocaceae	19	0.19	3.7	Ra
Symplocos paniculata Thunb.	Symplocaceae	13	0.05	2.3	Ra
Symplocos racemosa Roxb.	Symplocaceae	10	0.04	1.7	C
Viburnum odoratissimum Ker.	Caprifoliaceae	10	0.05	1.4	C
Wendlandia wallichii W. & A.	Rubiaceae	7	0.04	1.1	C
Zanthoxylum armatum DC.	Rubiaceae	23	0.33	4.4	Ra
Large climbers					
Acronychia pedunculata (Linn.) Miq.	Rutaceae	17	0.08	2.9	Ra
		1723	**27**	**300**	

*Re=regular, Ra=random, C=contagious distribution pattern.

Shrub species were represented by 20, 23 and 27 species belonging 18, 22 and 26 genera, and 13, 17 and 19 families in EG-I, II and III, respectively. In stand EG-I *Bridelia retusa, Callicarpa rubella, Elaeocarpus lancaefolius* and *Helicia excelsa* were common species (Table 5.1b), while *Citrus medica, Helicia nilagirica, Micromellum integerimum* and *Glochidion oblatum* were conspicuous in EG-II (Table 5.2b), and *Helicia nilagirica, Litsea salicifolia, Myrica esculenta* and *Symplocos racemosa* were of common occurrence in EG-III (Table 5.3b).

The tree seedlings, annual and perennial flowering plants and ferns constituted the ground layer in the forest. 44 species, 38 genera and 32 families in EG-I, 35 species, 34 genera and 31 families in EG-II, and 47 species, 40 genera and 22 families, in EG-III, represented the herbs. *Colquhounia coccinea, Hypericum laxum, Jasminium nervosum, Senecio cappa, Gleichenia* sp., *Asplenium* sp., *Cyperus pilosus, Homonoia riparia* and *Polygonum capitatum* were common species of the ground vegetation (Table 5.1c, 5.2c and 5.3c).

Lauraceae was the dominant (11 species) family in stand EG-I followed by Euphorbiaceae (7 species), Clusiaceae (5 species) and Rubiaceae (4 species). Seven families were represented by three species, 9 families by two species and rest 16 families were represented by single species. Based on family importance value, Lauraceae was the dominant (FIV 37.4) family followed by Euphorbiaceae (FIV 30.2), Fagaceae (FIV 21.6) and Clusiaceae (FIV 19.6) (Table 5.4).

Euphorbiaceae (12 species) was the most species-rich family in EG-II followed by Rutaceae (7 species), Lauraceae and Rubiaceae (5 species each),

Table 5.1b. Frequency (%), density (individuals ha^{-1}) and importance value index of shrub species in stand I of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Dracaena angustifolia Roxb.	Dracaenaceae	227	33	24.5
Rubus ellipticus Sm.	Rosaceae	160	30	19.5
Litsea salicifolia (Roxb. ex Nees.) Hk. f.	Lauraceae	147	27	17.6
Viburnum coriaceum Bl.	Caprifoliaceae	147	27	17.6
Mussaenda corymbosa Roxb.	Rubiaceae	147	20	15.3
Skimmia laureola (DC.) Sieb. & Zucc. ex Walp.	Rutaceae	120	20	13.8
Pteracanthus griffithianus Nees.	Acanthaceae	107	20	13.0
Bridelia retusa (Linn.) Spreng.	Euphorbiaceae	107	17	11.8
Psychotria denticulata Wall.	Rubiaceae	107	13	10.7
Lasianthus hookeri Cl. ex Hk. f.	Rubiaceae	80	17	10.3
Symplocos paniculata (Thunb.) Miq.	Symplocaceae	120	10	10.3
Dracaena elliptica Thunb.	Dracaenaceae	80	13	9.2
Gardneria ovata Wall.	Rubiaceae	53	10	6.5
Cryptolepis sinensis (Lour.) Merr.	Asclepiadaceae	40	7	4.6
Boehmeria platyphylla D. Don.	Urticaceae	27	7	3.8
Ficus hirta Vahl	Moraceae	27	7	3.8
Celastrus stylosus Roxb.	Celastraceae	13	3	1.9
Dendrocnide sinuata (Bl.) Chew.	Urticaceae	13	3	1.9
Litsea lancifolia (Roxb. ex Nees.) Wall. ex Hk. f.	Lauraceae	13	3	1.9
Morinda angustifolia Roxb.	Rubiaceae	13	3	1.9
		1747		**200**

Table 5.2b. Frequency (%), density (individuals ha^{-1}) and importance value index of shrub species in stand II of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Randia wallichii Hk. f.	Rubiaceae	278	57	18.5
Celastrus stylosus Roxb.	Celastraceae	244	57	17.4
Acacia pennata (Linn.) Willd.	Mimosaceae	211	47	14.7
Psychotria denticulata Wall.	Rubiaceae	200	43	13.8
Artidesma vulgaris Linn.	Asteraceae	211	40	13.6
Clausena heptaphylla (Roxb.) W. & A.	Rutaceae	200	40	13.2
Litsea salicifolia (Roxb. ex Nees.) Hk. f.	Lauraceae	156	43	12.3
Maesa indica (Roxb.) Wall.	Myrsinaceae	189	30	11.2
Euonymus attenuatus Laws.	Celastraceae	178	30	10.8
Daphne shillong Banerzi	Thymeliaceae	167	23	9.4
Cleirodendrum wallichii Merr.	Verbenaceae	144	23	8.6
Rhus javanica Linn.	Anacardiaceae	123	27	8.4
Cryptolepis sinensis (Lour.) Merr.	Asclepiadaceae	111	20	7.0
Antidesma acuminatum Wall.	Euphorbiaceae	89	23	6.8
Skimmia laureola (DC.) Sieb. & Zucc.ex Walp.	Rutaceae	100	20	6.6
Neillia thyrsiflora D. Don.	Rosaceae	89	20	6.2
Olax acuminata Benth.	Oleaceae	78	17	5.3
Rubus ellipticus Sm.	Rosaceae	67	13	4.4
Gardenia ovata Wall.	Rubiaceae	56	7	2.9
Viburnum foetidum Wall.	Caprifoliaceae	56	7	2.9
Symplocos paniculata (Thunb.) Miq.	Symplocaceae	33	10	2.8
Sarchochlamys pulcherrima Gaud.	Urticaceae	23	7	1.8
Psychotria erratica Hk. f.	Rubiaceae	23	3	1.3
		3023		**200**

Table 5.3b. Frequency (%), density (individuals ha^{-1}) and importance value index of shrub species in stand III of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Eurya japonica Thunb.	Theaceae	138	20	14.5
Coffea khasiana Hk.f.	Rubiaceae	138	77	13.4
Symplocos paniculata Thunb.	Symplocaceae	160	20	12.1
Goldfussia echinata Nees.	Acanthaceae	120	23	11.3
Casearia vareca Roxb.	Flacourtiaceae	102	20	11.1
Viburnam foetidum Hk.f & Th.	Caprifoliaceae	142	43	10.6
Psychotria symplocifolia Kurz.	Rubiaceae	98	67	10.6
Neillia thyrsiflora D.Don.	Rosaceae	93	20	9.8
Pleracanthus griffithianus Nees.	Acanthaceae	62	27	9.7
Actinidia callosa Lindl.	Actinidiaceae	102	23	8.7
Randia longiflora Lam.	Rubiaceae	80	20	7.4
Berberis wallichiana DC.	Berberidaceae	67	27	7.3
Leptodermis griffithii Hk.f.	Rubiaceae	71	13	7.2
Gaultheria fragrantissima Wall.	Ericaceae	71	10	6.9
Hypericum uralum Buch.-Ham.	Hypericaceae	71	20	6.9
Litsea salicifolia (Roxb.ex Nees) Hk.f.	Lauraceae	67	10	6.7
Psychotria erratica Hk.f.	Rubiaceae	62	10	6.5
Zanthoxylum khasianum Hk.f.	Rutaceae	84	10	5.8
Mussaenda glabra Vahl.	Rubiaceae	58	7	5.1
Euonymus attenuatus Laws.	Celastraceae	49	3	4.4
Premna barbata Wall. ex Sch.	Verbenaceae	40	17	4.3
Chloranthus glaber Thunb.	Chloranthaceae	44	3	4.2
Ardisia odontophylla DC.	Myrsinaceae	40	3	4.0
Polyalthia cerasoides Roxb.	Annonaceae	40	13	4.0
Leucosceptrum canum Smith	Lamiaceae	31	7	3.0
Salix psilostigma Anders.	Salicaceae	31	13	2.7
Gardenia companulata Roxb.	Rubiaceae	18	10	1.7
		2080		**200**

Table 5.1c. Frequency (%), density (plant 100m^2) and importance value index of herbaceous species in stand I of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Asplenium spp.	Asteraceae	199	85	23.1
Gleichenia sp.	Gleicheniaceae	188	90	20.9
Pothos scandens Linn.	Taccaceae	88	61	11.6
Elatostemma rupestre (D. Don.) Wedd.	Gesneriaceae	82	60	11.1
Drymaria cordata Linn.	Gesneriaceae	68	56	9.8
Jasminum dispermum Wall.	Orchidaceae	65	53	9.4
Oxalis corniculata Linn.	Piperaceae	58	40	7.6
Polygonum barbatum Linn.	Rubiaceae	48	35	6.5
Davaellia sp.	Davaelliaceae	49	32	6.3
Tacca laevis Roxb.	Vaccinaceae	43	32	5.9
Dioscoria bulbifera Linn.	Fabaceae	39	27	5.1
Ophiorhiza mungos Linn.	Piperaceae	33	23	4.3
Smilax quadrata DC.	Urticaceae	31	23	4.2
Arisaema tortuosum (Wall.) Schott.	Asteraceae	27	24	4.1
Commelina benghalensis Linn.	Asteraceae	29	23	4.1
Osmunda javanica	Piperaceae	34	19	4.1
Galinsoga parviflora Cav.	Hypoxidaceae	28	22	3.9
Piper longum Linn.	Polypodiaceae	30	20	3.9
Tainia latifolia (Lindl.) Hk. f.	Violaceae	26	23	3.9
Paederia foetida Linn.	Poaceae	28	21	3.9
Viola palmaris Ging.	Zingiberaceae	24	16	3.1
Hiptage benghalensis (Linn.) Kurz.	Oleaceae	23	17	3.1
Hoya lanceolata Wall. ex D. Don.	Asclepiadaceae	23	16	3.0
Costus speciosus Sm.	Commelinaceae	22	16	2.9
Aeschynanthus superba Cl.	Asclepiadaceae	18	16	2.7
Polygonum chinense Linn.	Smilacaceae	24	12	2.7
Elatostema sessile Forst.	Glecheniaceae	20	14	2.7
Hedychium coccineum Smith.	Malpighiaceae	18	13	2.4
Lindernia multiflora (Roxb.) Mukarjee	Orchidaceae	18	13	2.4
Polygonum capitatum D. Don.	Scrophulariaceae	18	13	2.4
Agapetes variegata (Roxb.) G. Don	Aspleniaceae	19	9	2.1
Dendrobium sp.	Orchidaceae	16	9	1.9
Cyperus pilosus Vahl.	Cyperaceae	14	10	1.9
Mikania micrantha Kunth.	Osmundaceae	14	10	1.9
Aeschynanthus grandiflora D. Don.	Araceae	13	11	1.9
Hedyotis scandens D. Don.	Menispermaceae	16	7	1.7
Peperomia tetraphylla (Forst. f.) Hk.f. Arn.	Polygonaceae	14	8	1.6
Vernonia arborea Buch.-Ham.	Zingiberaceae	12	8	1.6
Pericampylus glaucus (Lamk.) Merr.	Polygonaceae	10	6	1.2
Piper sp.	Piperaceae	8	3	0.8
Swertia pulchella (D.Don.) Clarke.	Urticaceae	8	3	0.7
Disporum cantoniese (Lour.) Merr.	Gentianaceae	6	3	0.6
Molineria capitulata Lour.	Oxallidaceae	4	3	0.5
Pholidota imbricata Hook. f.	Polygonaceae	4	2	0.4
		1554		**200**

Table 5.2c. Frequency (%), density (plant 100m^2) and importance value index of herbaceous species in stand II of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Agave sisalana Engel.	Agavaceae	16	9	2.0
Arisaema tortuosum (Wall.) Schott.	Fabaceae	65	45	9.0
Asplenium sp.	Aspleniaceae	102	20	8.8
Curculigo orchioides Gaertn.	Hypoxidaceae	57	33	7.1
Cyanotis barbata	Commelinaceae	11	4	1.1
Cynodon ternatus A. Rich.	Cyperaceae	81	63	11.9
Cyperus pilosus Vahl.	Cyperaceae	73	54	10.5
Davaeillia sp.	Davalliaceae	203	98	23.4
Dracaena elliptica Thunb.	Agavaceae	18	13	2.5
Elatostemma rupestre (D. Don.) Wedd.	Urticaceae	3	1	0.3
Galinsoga parviflora Cav.	Asteraceae	65	53	9.8
Gleichenia sp.	Gleicheniaceae	114	74	15.2
Goldfussia discolor Nees.	Acanthaceae	27	23	4.1
Hedychium coccineum Smith	Zingiberaceae	52	40	7.6
Hedyotis scandens D. Don.	Rubiaceae	38	29	5.6
Hiptage benghalensis (Linn.) Kurz.	Malpighiaceae	48	30	6.3
Hoya lanceolata Wall. ex D. Don.	Asclepiadaceae	9	6	1.2
Lindernia multiflora (Roxb.) Mukerjee	Scrophulariaceae	33	22	4.4
Lycopodium sp.	Lycopodiaceae	58	44	8.4
Molineria capitulata Lour.	Hypoxidaceae	9	6	1.2
Osmunda javanica	Osmundaceae	48	35	6.8
Oxalis corniculata Linn.	Oxallidaceae	11	6	1.3
Paederia foetida Linn.	Poaceae	19	10	2.3
Piper longum Linn.	Piperaceae	88	60	12.0
Pogostemon auricularis Hask.	Acanthaceae	2	2	0.3
Polygonum capitatum D. Don.	Polygonaceae	16	9	2.0
Polygala glomerata Lour.	Polygalaceae	13	6	1.4
Pothos glaucus Wall.	Arecaceae	10	8	1.5
Pteris sp.	Pteridaceae	86	48	10.7
Sellaginella sp.	Sellaginaceae	72	60	11.0
Smilax ferox Kunth.	Smilaceae	43	34	6.4
Swertia pulchella D. Don.	Gentianaceae	3	2	0.4
Tacca laevis Roxb.	Taccaceae	3	3	0.4
Tainia latifolia (Lindl.) Hk. f.	Orchidaceae	4	2	0.5
Viola palmaris Ging.	Violaceae	24	11	2.7
		1523		**200**

Table 5.3c. Frequency (%), density (plant 100m^2) and importance value index of herbaceous species in stand III of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Hemiphragma hetrophyllum Wall.	Scrophulariaceae	181	94	20.5
Setaria palmifolia Koen. Stapf.	Poaceae	138	72	15.6
Paedaria foetida Linn.	Rubiaceae	94	77	13.4
Piper betel Linn.	Piperaceae	104	65	12.9
Senecio griffithii Clarke.	Asteraceae	103	60	12.3
Potentilla mooniana Wight.	Rosaceae	63	43	8.2
Cyperus esculentus Linn.	Cyperaceae	53	43	7.6
Colquhounia coccinea Wall.	Lamiaceae	56	37	7.1
Piper griffithii C. DC.	Piperaceae	60	33	6.9
Piper thomsonii Hk.f.	Piperaceae	54	28	6.1
Anotis calycina Hk. f.	Asteraceae	48	31	6.0
Osbeckia crinita Naud.	Melastomataceae	43	26	5.2
Gnaphalium affine D. Don.	Asteraceae	35	29	5.1
Digitaria corymbosa Roxb.	Poaceae	43	24	5.0
Hedera nepalensis K. Koch.	Araliaceae	43	23	4.9
Gerbera maxima D. Don.	Asteraceae	35	20	4.1
Desmodium triangulare (Reitz.) Merr.	Fabaceae	31	19	3.8
Sonchus radigatum Linn.	Asteraceae	32	18	3.8
Ainsliaea latifolia (D.Don.) Sch.	Asteraceae	16	24	3.4
Scutelleria discolor Coleb.	Labiateae	29	15	3.3
Plantago major Linn.	Plantaginaceae	27	16	3.2
Polygonum nepalense Meissn.	Polygonaceae	32	13	3.2
Swertia pulchella D. Don.	Gentianaceae	22	16	2.9
Rubia cordifolia Linn.	Rubiaceae	21	13	2.6
Echinochloa frumentacea Link.	Poaceae	19	14	2.6
Gleichenia sp.	Gleicheniaceae	18	15	2.6
Rubus hexagynus Roxb.	Rosaceae	21	12	2.4
Davaellia sp.	Davaelliaceae	19	13	2.4
Lindernia multiflora (Roxb) Mukerjii	Scrophulariaceae	23	10	2.4
Smilax aspera Linn.	Smilacaceae	18	8	2.0
Hypericum laxum Bl.	Hypericaceae	15	10	1.9
Asplenium sp.	Aspleniaceae	13	11	1.8
Elatostemma rupestre (D.Don) Wedd.	Asteraceae	13	8	1.6
Viola diffusa Gmg.	Violaceae	16	6	1.6
Rubia sp.	Rubiaceae	11	8	1.4
Smithia ciliata Wall.	Fabaceae	10	8	1.4
Anaphalis timmua D. Don.	Asteraceae	11	6	1.2
Pueraria lobata DC.	Asteraceae	9	6	1.1
Eleusine coracana Gaertn.	Eragrosteae	11	4	1.1
Senecio cappa Buch.-Ham. ex D. Don.	Asteraceae	11	4	1.1
Fagraea ceilanica Thunb.	Rosaceae	9	4	1.0
Acanthopanax aculeatum Seem.	Araliaceae	6	3	0.7
Paspallum dilatatum Poir.	Poaceae	6	3	0.7
Lindernia crustacea (Linn.) F.	Scrophulariaceae	4	4	0.7
		1635		**200**

Table 5.4. Importance values of different families in stand I of the evergreen forest.

Family rank	Family	Species	Individuals (ha^{-1})	Basal cover (m^2 ha^{-1})	*FIV
1	Lauraceae	11	123	4.0	37.4
2	Euphorbiaceae	7	95	4.1	30.2
3	Fagaceae	3	81	3.4	21.6
4	Clusiaceae	5	83	1.7	19.4
5	Verbenaceae	2	58	3.3	18.1
6	Myrsinaceae	3	46	2.2	14.9
7	Moraceae	2	40	2.1	12.5
8	Rubiaceae	4	46	0.6	11.3
9	Rosaceae	3	38	0.9	10.1
10	Annonaceae	3	30	0.9	9.4
11	Elaeocarpaceae	3	37	0.7	9.3
12	Sapindaceae	3	24	0.9	8.7
13	Rutaceae	2	33	0.9	8.4
14	Myrtaceae	3	23	0.6	7.6
15	Proteaceae	2	29	0.7	7.4
16	Juglandaceae	1	27	1.1	7.2
17	Thymeliaceae	1	13	1.5	7.1
18	Theaceae	2	19	0.5	5.9
19	Araliaceae	2	11	0.4	4.7
20	Tetrastromiaceae	1	18	0.4	4.2
21	Sapotaceae	2	13	0.2	4.2
22	Sterculiaceae	1	23	0.2	4.0
23	Urticaceae	2	10	0.1	3.6
24	Taxaceae	1	18	0.2	3.6
25	Ebenaceae	2	7	0.1	3.5
26	Caprifoliaceae	1	11	0.2	3.0
27	Anacardiaceae	1	7	0.3	2.9
28	Meliaceae	1	10	0.2	2.7
29	Celastraceae	1	10	0.2	2.7
30	Myricaceae	1	7	0.2	2.4
31	Arecaceae	1	7	0.2	2.4
32	Asteraceae	1	6	0.1	2.1
33	Sonneratiaceae	1	4	0.2	2.1
34	Flacourtiaceae	1	6	0.1	2.0
35	Saurauiaceae	1	4	0.1	1.9
36	Capparidaceae	1	4	0.0	1.7
		82	**1021**	**33.3**	**300**

*Family Importance Value

and Moraceae and Myrtaceae (4 species each). Fabaceae was the dominant family (FIV 43.7), followed by Euphorbiaceae (FIV: 38.7) (Table 5.5).

Among the tree species, Lauraceae (represented by 10 species) was dominant in EG-III followed by Rubiaceae (8 species), Euphorbiaceae (7 species), Theaceae (5 species), Rosaceae and Elaeocarpaceae (4 species each). There were 9 families with 2 species each and 17 families with one species each (Table 5.6). Based on FIV too, Lauraceae (41.8) was the dominant family followed by Rubiaceae (35.5) and Anacardiaceae (32.9).

Dominance-distribution of FIV showed that only few families (Lauraceae, Euphorbiaceae, Theaceae, Fagaceae, Rubiaceae and Rosaceae) were dominant in all the three forest stands, while the large number of families represented by few species, had low FIV values (Fig. 5.1).

Community structure

Life form spectrum

Life form spectra presented in Figure 5.2 showed preponderance of phanerophytes (*ca.* 55%) in all the three stands. They were followed by chamaephytes (19%), and therophytes (9% to 14%). The proportion of phanerophytes is about 10% less than the tropical rain forest where they constitute about 65% of the species in the community (Raunkiaer 1934).

Vertical structure

Profile diagrams drawn along 30 m long and 5 m wide transects reveal that trees are well stratified into three distinct strata namely, canopy (> 20 m height) layer, sub-canopy (10-20 m) layer and treelet (2-10 m) layer. In stand

Table 5.5. Importance values of different families in stand II of the evergreen forest.

Family rank	Family	Species	Individuals (ha^{-1})	Basal cover ($m^2\ ha^{-1}$)	*FIV
1	Fabaceae	4	103	12.6	43.7
2	Euphorbiaceae	12	122	5.2	38.7
3	Rutaceae	7	50	1.5	16.6
4	Lauraceae	5	52	1.6	15.0
5	Moraceae	4	32	3.1	14.8
6	Rubiaceae	5	38	1.3	12.8
7	Meliaceae	3	35	2.0	11.7
8	Elaeocarpaceae	2	33	2.4	11.3
9	Symplocaceae	3	31	1.9	11.0
10	Myrtaceae	4	24	0.7	8.7
11	Sapindaceae	2	26	1.5	8.5
12	Mimosaceae	2	28	1.0	7.7
13	Theaceae	2	24	0.7	6.5
14	Ebenaceae	2	18	0.9	6.3
15	Malvaceae	1	16	1.5	6.1
16	Combretaceae	2	10	1.1	5.7
17	Anacardiaceae	2	17	0.7	5.7
18	Araliaceae	2	19	0.5	5.5
19	Pandanaceae	1	19	0.7	4.8
20	Myrsinaceae	1	14	0.9	4.7
21	Flacourtiaceae	1	16	0.6	4.3
22	Celastraceae	2	11	0.3	4.0
23	Magnoliaceae	2	6	0.5	4.0
24	Arecaceae	1	14	0.6	4.0
25	Tetrameliaceae	1	11	0.6	3.8
26	Verbenaceae	2	6	0.2	3.3
27	Urticaceae	2	5	0.2	3.2
28	Rhamnaceae	2	5	0.2	3.1
29	Ulmaceae	1	10	0.4	3.1
30	Sonneratiaceae	1	6	0.5	3.0
31	Caprifoliaceae	2	5	0.1	2.9
32	Sterculiaceae	2	3	0.2	2.9
33	Clusiaceae	2	4	0.1	2.8
34	Saurauiaceae	2	3	0.1	2.6
35	Thymeliaceae	1	7	0.2	2.3
33	Menispermaceae	1	5	0.1	1.9
37	Simaroubaceae	1	4	0.1	1.8
38	Aquifoliaceae	1	2	0.0	1.4
		93	**834**	**46.4**	**300**

* Family Importance Value

Table 5.6. Importance values of different families in stand III of the evergreen forest.

Family rank	Family	Species	Individuals (ha^{-1})	Basal cover (m^2 ha^{-1})	*FIV
1.	Lauraceae	10	193	4.7	41.8
2.	Rubiaceae	8	232	3.1	35.5
3.	Anacardiaceae	2	252	4.2	32.9
4.	Euphorbiaceae	7	102	1.8	21.8
5.	Theaceae	5	157	1.5	21.4
6.	Moraceae	2	188	1.0	17.4
7.	Rosaceae	4	65	2.0	16.6
8.	Elaeocarpaceae	4	41	0.7	10.2
9.	Corylaceae	1	13	1.5	7.7
10.	Symplocaceae	3	42	0.3	7.4
11.	Ebenaceae	1	53	0.6	6.5
12.	Celastraceae	2	37	0.4	6.4
13.	Berberidaceae	1	21	0.9	5.8
14.	Verbenaceae	1	53	0.4	5.7
15.	Lamiaceae	1	10	0.8	4.8
16.	Meliaceae	1	27	0.4	4.5
17.	Oleaceae	2	22	0.1	4.4
18.	Araliaceae	2	18	0.2	4.3
19.	Ericaceae	2	11	0.2	4.0
20.	Aquifoliaceae	2	14	0.1	3.7
21.	Juglandaceae	1	21	0.3	3.7
22.	Proteaceae	2	11	0.1	3.6
23.	Simaroubaceae	1	27	0.2	3.5
24.	Clusiaceae	2	6	0.1	3.4
25.	Erythroxylaceae	1	20	0.2	3.4
26.	Acanthaceae	1	9	0.4	3.3
27.	Flacourtiaceae	1	23	0.1	3.2
28.	Daphniphyllaceae	1	3	0.3	2.7
29.	Rutaceae	1	17	0.1	2.6
30.	Hamamelidaceae	1	11	0.1	2.1
31.	Caprifoliaceae	1	10	0.1	2.1
32.	Malvaceae	1	10	0.1	2.1
33.	Myricaceae	1	4	0.0	1.7
		76	**1723**	**27.0**	**300**

* Family Importance Value

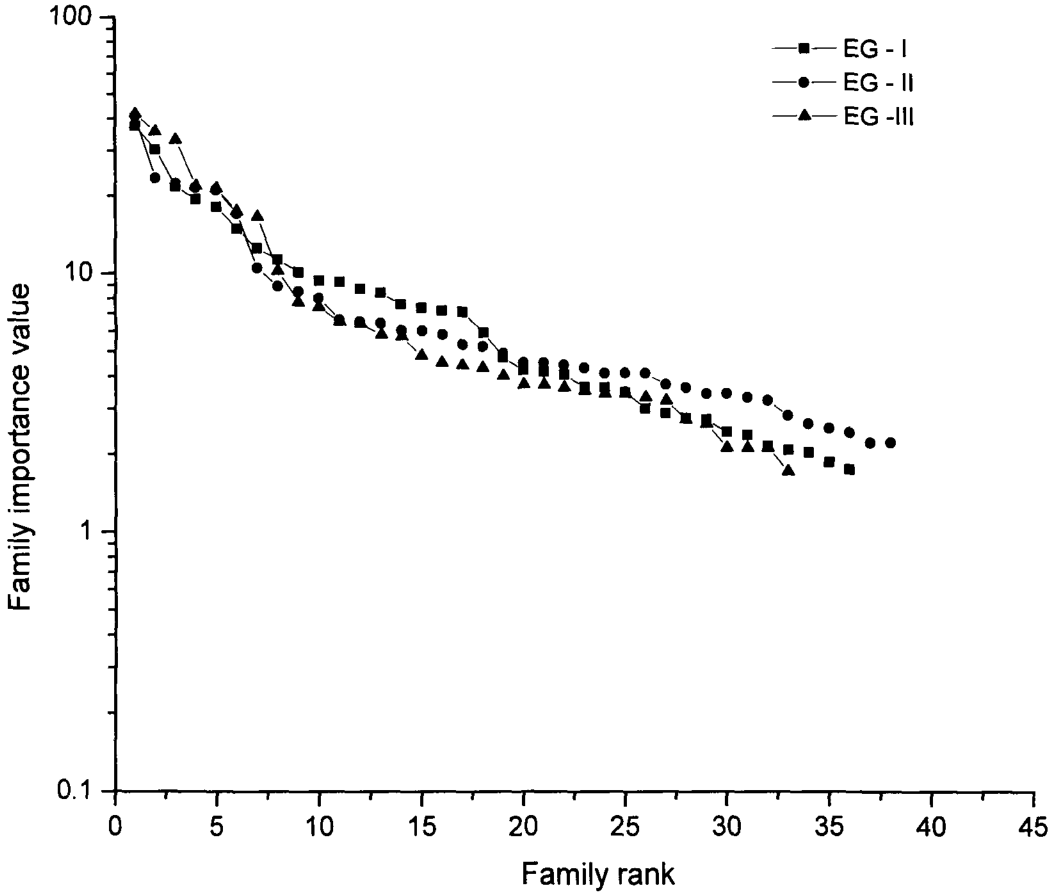


Fig. 5.1. Dominance-distribution in different families of tree species (family names are given in Table 5.4, 5.5, 5.6) in the subtropical evergreen forest.

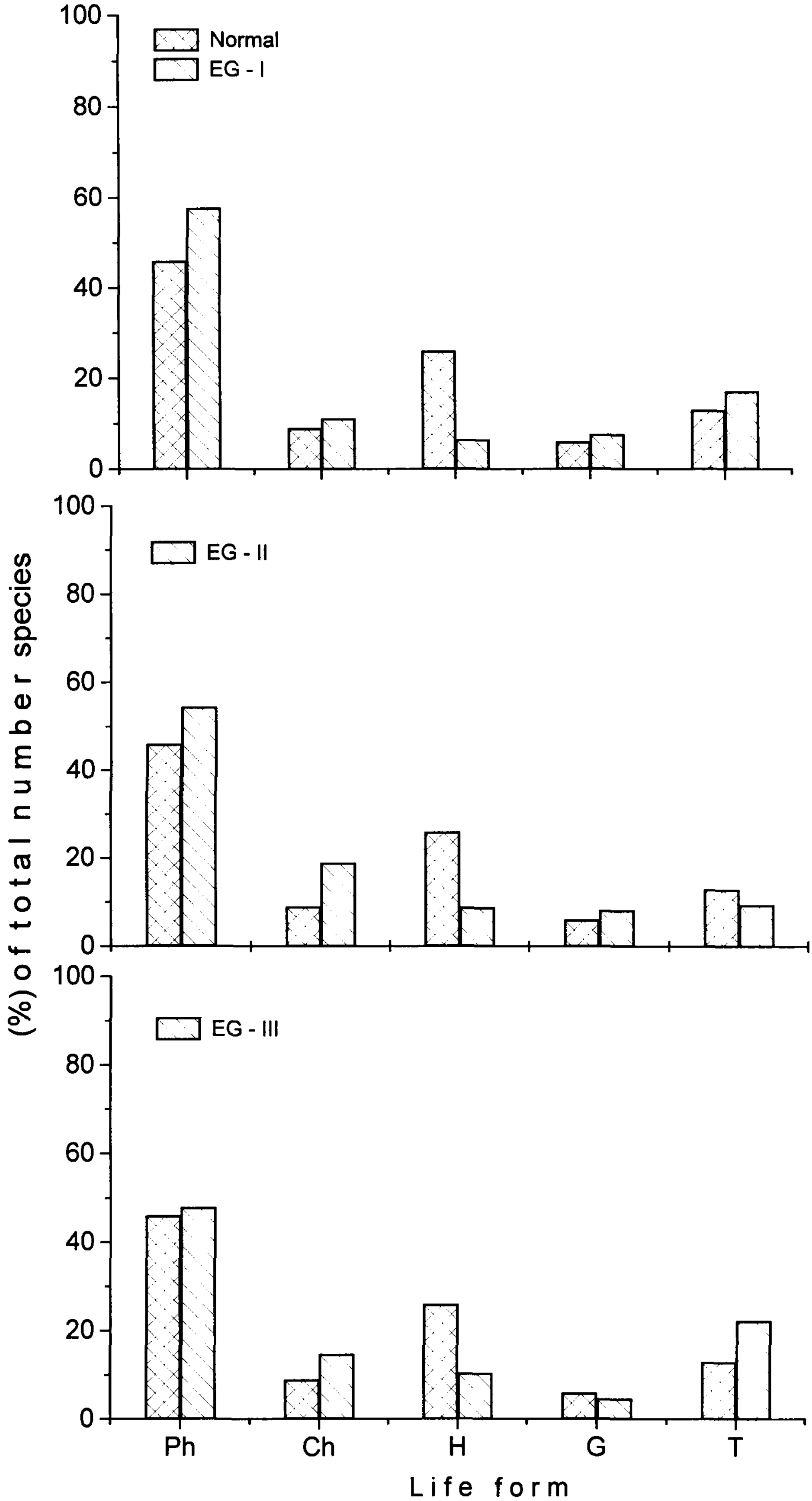


Fig. 5.2. Life form spectra of the three (EG - I, EG - II, EG - III) of the subtropical evergreen forest (Ph - Phanerophytes, Ch - Chamaephytes, H - Hemicryptophytes, G - Geophytes, T - Therophytes).

EG–I, the canopy layer was composed mainly of species like *Castanopsis indica*, *C. purpurella*, *Beilshmiedia assamica*, and *Callicarpa arborea.* The sub-canopy was formed by *Duabanga grandiflora*, *Psychotria symplocifolia*, *Helicia nilagirica* and *Ficus nervosa*. *Elaeocarpus acuminata, Eurya acuminata, Saprosma ternatum* and *Syzygium cuminii* were common species of the treelet layer (Fig. 5.3).

In the stand EG–II, *Castanopsis purpurella*, *Macaranga denticulata*, *Mallotus philippensis* and *Duabanga grandiflora* were common tree species of the canopy layer. *Beilshmiedia assamica*, *Derris robusta*, *Casearia vareca* and *Echinocarpus murex* were present in the sub-canopy layer, while *Aporusa oblonga*, *Citrus medica*, *C. hystrix* and *Persea duthiei* were common in the treelet layer (Fig. 5.4).

In EG–III, the canopy layer was composed of *Cryptocarya andersonii*, *Dysoxylum binectariferum*, *Echinocarpus dasycarpus*, *Schima wallichii*, *Rhododendron arboreum* and *Euonymus lawsonii,* while the sub-canopy was made up of species like *Aporusa wallichii*, *A. oblonga*, *Helicia nilagirica*, *Kydia calycina, Cryptocarya andersonii, Beilshmiedia roxburghiana* and *Olax acuminata*. The common species in the treelet layer were *Euonymus lawsonii*, *Echinocarpus murex*, *Cinnamomum pauciflorum, Eurya acuminata* and *Pyrus pashia* (Fig. 5.5).

Distribution pattern of species

Majority of the tree species in the forest were contagiously distributed (Table 5.7). Out of 82, 93 and 76 tree species, only 14-26 species were

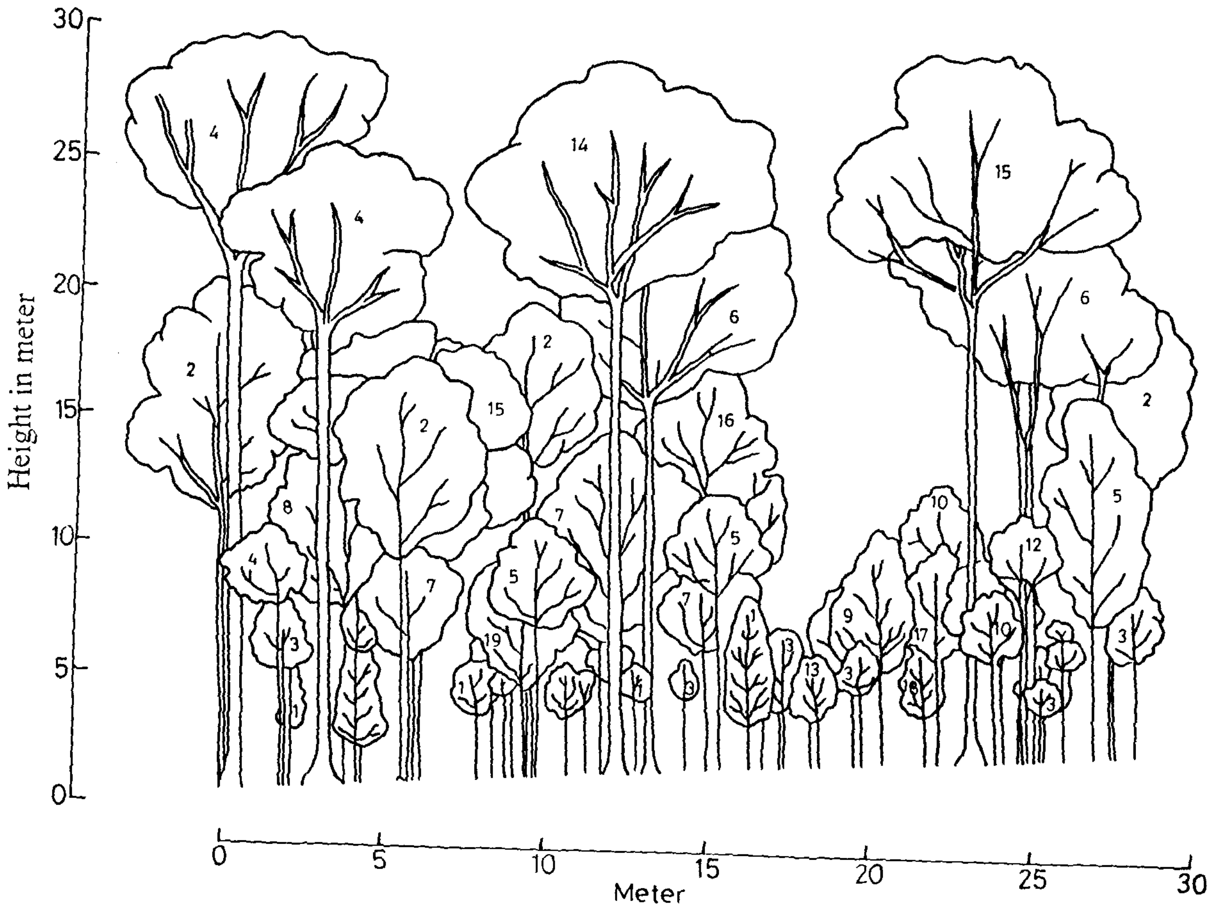


Fig. 5.3. Profile diagram of a subtropical evergreen (EG - I) forest. The diagram represents a strip of forest (30 m long and 5 m wide). 1. *Citrus hystrix*, 2. *Beilshmiedia assamica*, 3. *Eurya acuminata*, 4. *Castanopsis indica*, 5. *Elaeocarpus acuminatus*, 6. *Ficus nervosa*, 7. *Cinnamomum pauciflorum*, 8. *Duabanga grandiflora*, 9. *Engelhardtia spicata*, 10. *Syzygium cuminii*, 11. *Saprosma ternatum*, 12. *Callicarpa arborea*, 13. *Litsea salicifolia*, 14. *Castanopsis purpurella*, 15. *Euonymus lawsonii*, 16. *Glochidion assamicum*, 17. *Psychotria symplocifolia*, 18. *Helicia nilagirica*.

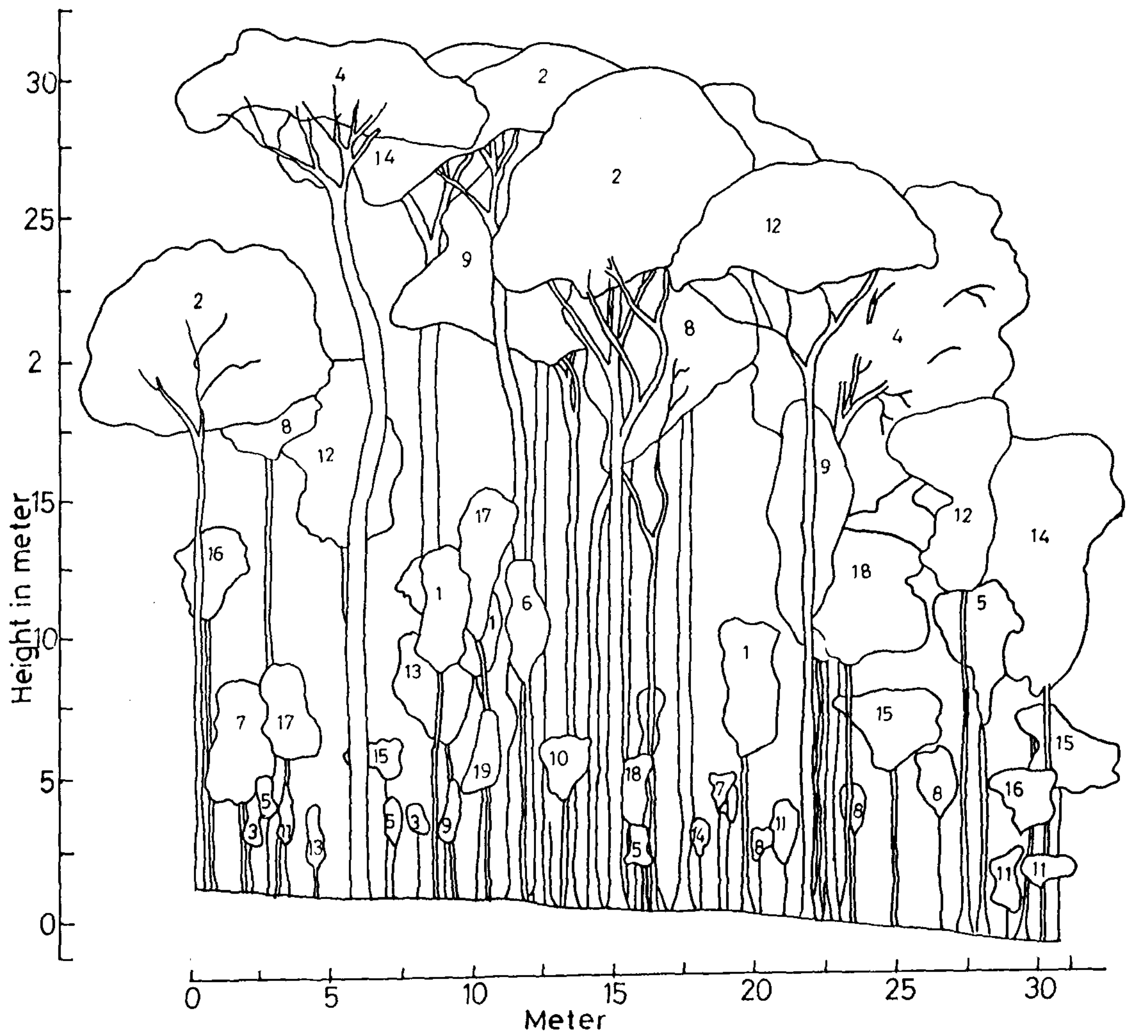


Fig. 5.4. Profile diagram of a subtropical evergreen (EG-II) forest. The diagram represents a strip of forest (30 m long and 5 m wide). 1. *Aporusa oblonga*, 2. *Beilschmeidia assamica*, 3. *Citrus medica*, 4. *Castanopsis purpurella*, 5. *Casearia vereca*, 6. *Duabunga grandiflora*, 7. *Dysoxylum binectariferum*, 8. *Derris robusta*, 9. *Ficus elastica*, 10. *Echinocarpus murex*, 11. *Glycosmis arborea*, 12. *Persea duthiei*, 13. *Symplocos paniculata*, 14. *Macaranga denticulata*, 15. *Mallotus phillipensis*, 16. *Symplocos racemosa*, 17. *Terminalia bellerica*, 18. *Psychotria symplocifolia*, 19. *Randia wallichii*.

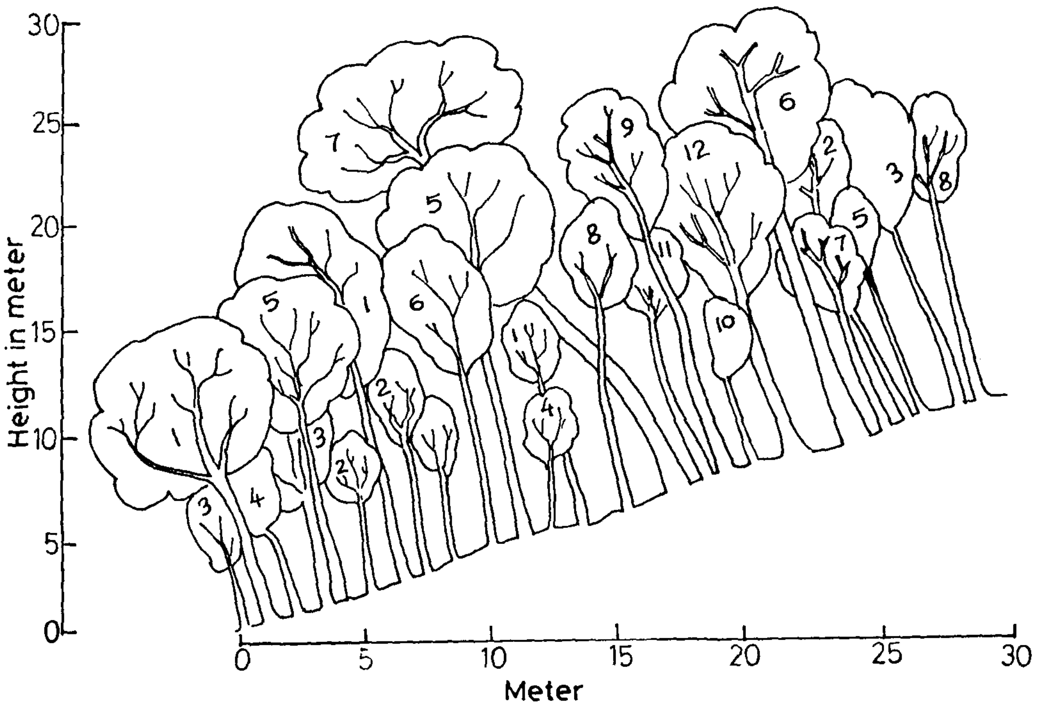


Fig. 5.5. Profile diagram of a subtropical evergreen (EG-III) forest. The diagram represents a strip of forest (30 m long and 5 m wide). 1.*Beilshmiedia roxburghiana*, 2. *Cryptocarya andersonii*, 3. *Daphniphyllum himalayense*, 4. *Aporusa oblonga*, 5. *Euonymus lawsonii*, 6. *Kydia calycina*, 7. *Rhododendron arboreum*, 8. *Helicia nilagirica*, 9. *Myrica esculenta*, 10. *Symplocos racemosa*, 11. *Garcinia cowa*, 12. *Olax acuminata*.

randomly distributed. The number of species showing regular distribution varied between 4 and 12. Greater proportion of contagiously distributed tree species made the forest community highly patchy in nature.

Table 5.7. Distribution pattern and Whitford index of trees (T), shrubs (S) and herbaceous (H) species in the three subtropical evergreen forest stands. Values in parentheses are the percentage of the total number of species in a given stand.

Distribution pattern	EG-I			EG-II			EG-III		
	T	S	H	T	S	H	T	S	H
Regular	12 (14.6)	0	6 (13.6)	4 (4.3)	2 (8.7)	7 (20)	5 (6.6)	0	3 (6.4)
Random	26 (31.7)	1 (5)	5 (11.4)	14 (15.1)	6 (26.1)	7 (20)	24 (31.6)	5 (18.5)	7 (14.9)
Contagious	44 (53.7)	19 (95)	33 (75)	75 (80.6)	15 (65.2)	21 (60)	47 (61.8)	22 (81.5)	37 (78.7)
	82 (100)	20 (100)	44 (100)	93 (100)	23 (100)	35 (100)	76 (100)	27 (100)	47 (100)

Frequency

In all three stands majority of the tree species (53% to 72%) showed low frequency (<20%), while 28 to 47% species were distributed among the higher frequency classes (Fig. 5.6). *Saprosma ternatum*, *Macaranga indica*, *Citrus hystrix*, *Castanopsis indica* and *Callicarpa vestita* in stand EG–I, *Syzygium cuminii*, *Elaeocarpus lancaefolius*, *Glycosmis arborea*, *Dysoxylum binectaeriferum* and *Castanopsis kurzii* in stand EG–II, and *Aporusa oblonga*, *Beilshmiedia roxburghiana*, *Engelhardtia spicata*, *Neoloitsea pallens* and *Euonymus attenuatus* in stand EG–III were among the most frequently found tree species in the community.

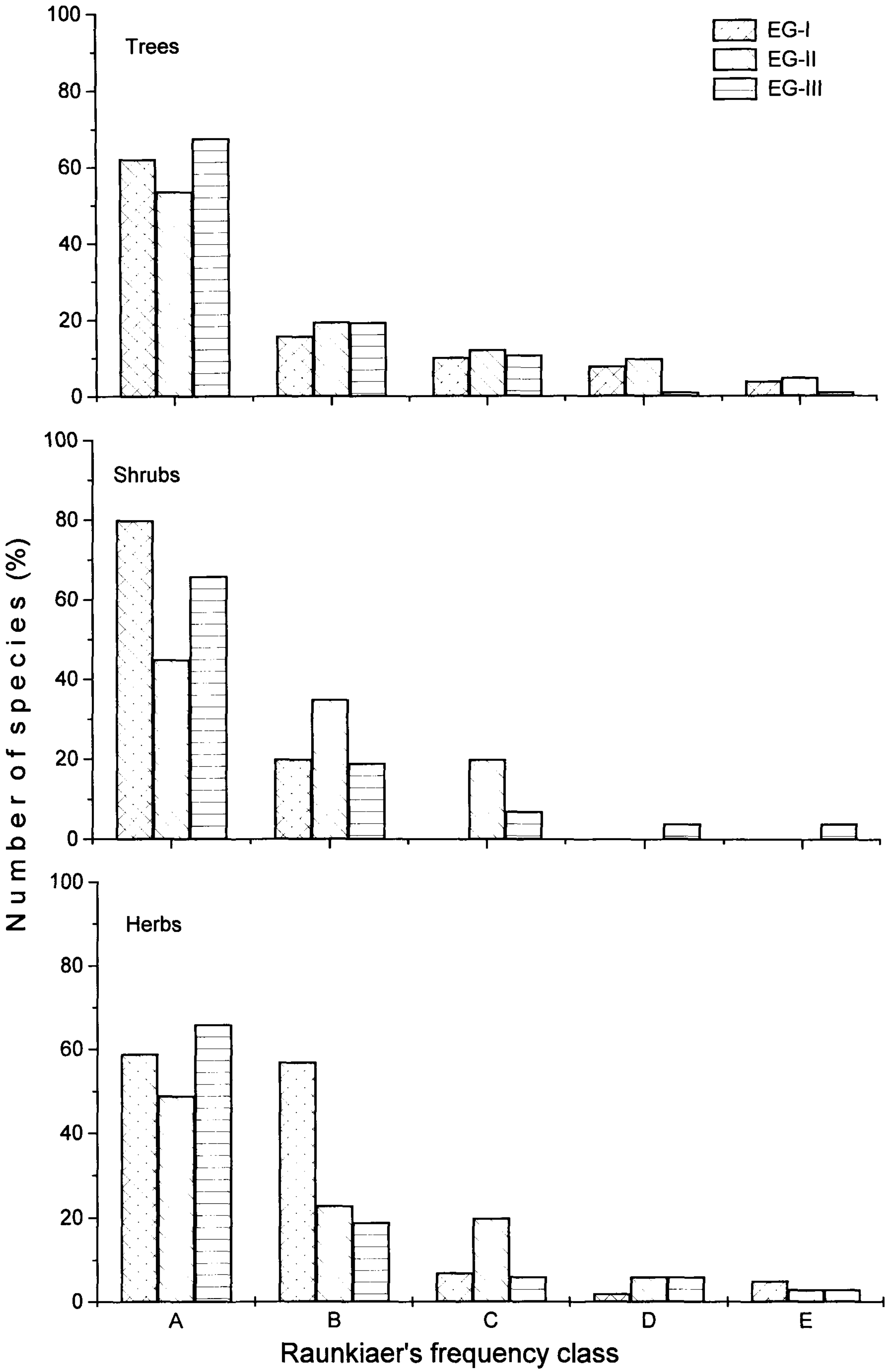


Fig. 5.6. Distribution of plant species in different frequency classes in three stands (EG-I, EG-II, EG-III) of the subtropical evergreen forest.

Among shrub species 45% to 80% species had low frequency (<20%) in all the three stands. In EG–II and I, frequency classes D and E were completely absent (Fig. 5.6). In these stands *Dracaena aungustifolia*, *Rubus ellipticus*, *Randia wallichii*, *Celastrus stylosus*, *Eurya japonica* and *Coffea khasiana* were most frequent species (Table 5.1b, 5.2b, 5.3b). About 50–66% of the herbaceous species had <20% frequency in the three forest stands (Fig. 5.6). *Hemiphragma heterophyllum*, *Setaria polmifolia*, *Paedaria foetida* and *Seneceo griffithii* and ferns like *Asplenium* sp., *Glechenia* sp., *Davaellia* sp. had high frequency values (Table 5.1c, 5.2c, 5.3c).

Stand density and basal cover

The density of tree species was 1023 ±23, 834 ±17 and 1723 ±13 stems ha^{-1} in the stands EG-I, II and III, respectively. The basal cover was 38.8 ±2.22 m^2 ha^{-1} in the stand EG-II, followed by EG-I (33.34 ±. 0.59 m^2 ha^{-1}), and EG-III (26.99 ±1.14 m^2 ha^{-1}) (Table 5.8).

Table 5.8. Mean stand density (individuals ha^{-1}) and mean basal cover (m^2 ha^{-1}) of tree species in the subtropical evergreen forest.

	Subtropical evergreen forest		
	EG-I	**EG-II**	**EG-III**
Stand density	1023 ±21	834 ±17	1723 ±15
Basal cover	33.34 ±0.59	38.8 ±2.22	26.99 ±1.14

In terms of density, *Callicarpa vestita* (38 stem ha^{-1}), *Castanopsis indica* (32 stem ha^{-1}), *Citrus hystrix* (30 stem ha^{-1}), *C. tribuloides* (28 stem ha^{-1}) and *Engelhardtia spicata* (27 stem ha^{-1}) in stand EG–I, *C. kurzii* (58 stem ha^{-1}), *Elaeocarpus lancifolius* (25 stem ha^{-1}), *Persea duthiei* (25 stem ha^{-1}), *Derris robusta* (23 stem ha^{-1}) and *Symplocos paniculata* (20 stem ha^{-1}) in EG–II and *Rhus javanica* (233 stem ha^{-1}), *Ficus elastica* (178 stem ha^{-1}), *Saprosma ternatum* (102 stem ha^{-1}), *Diospyrous pilosula* (53 stem ha^{-1}) and *Eurya japonica* (57 stem ha^{-1}) in stand EG–III were dominant tree species. They together accounted for 15%, 18% and 36%of total stand density in the stands EG-I, II and III, respectively.

Distribution of stand density in different girth classes revealed that trees of middle girth (35-75 cm cbh) accounted for 60%, 55% and 82% of the total stand density in EG - I, II and III, respectively. Trees beyond >95 cm girth class accounted for only 5%, 20% and 2% of the total stand density in the stands EG–I, II and III, respectively (Fig. 5.7).

Distribution of basal cover in different girth classes showed a reverse trend, that is, trees of higher girth classes, though less in number, contributed maximum basal cover in EG - II followed by individuals of middle girth class (35-75 cm cbh). In the stands EG-III and I, middle girth classes contributed maximum to the basal cover followed by trees of higher girth classes (Fig. 5.8).

Dominance

In terms of importance value, *Vitex vestita* (IVI: 12), *Castanopsis indica* (IVI: 12.7), *Citrus hystrix* (IVI: 9.2), *Castanopsis tribuloides* (IVI: 9.5) and *Engelhardtia spicata* (IVI: 8.6) were dominant tree species in stand EG–I. *Castanopsis kurzii* (IVI: 28.9), *Persea duthiei* (IVI: 7.1), *Elaeocarpus lancaefolius* (IVI: 11.4), *Derris robusta* (IVI: 5.2) and *Psychotria symplocifolia*

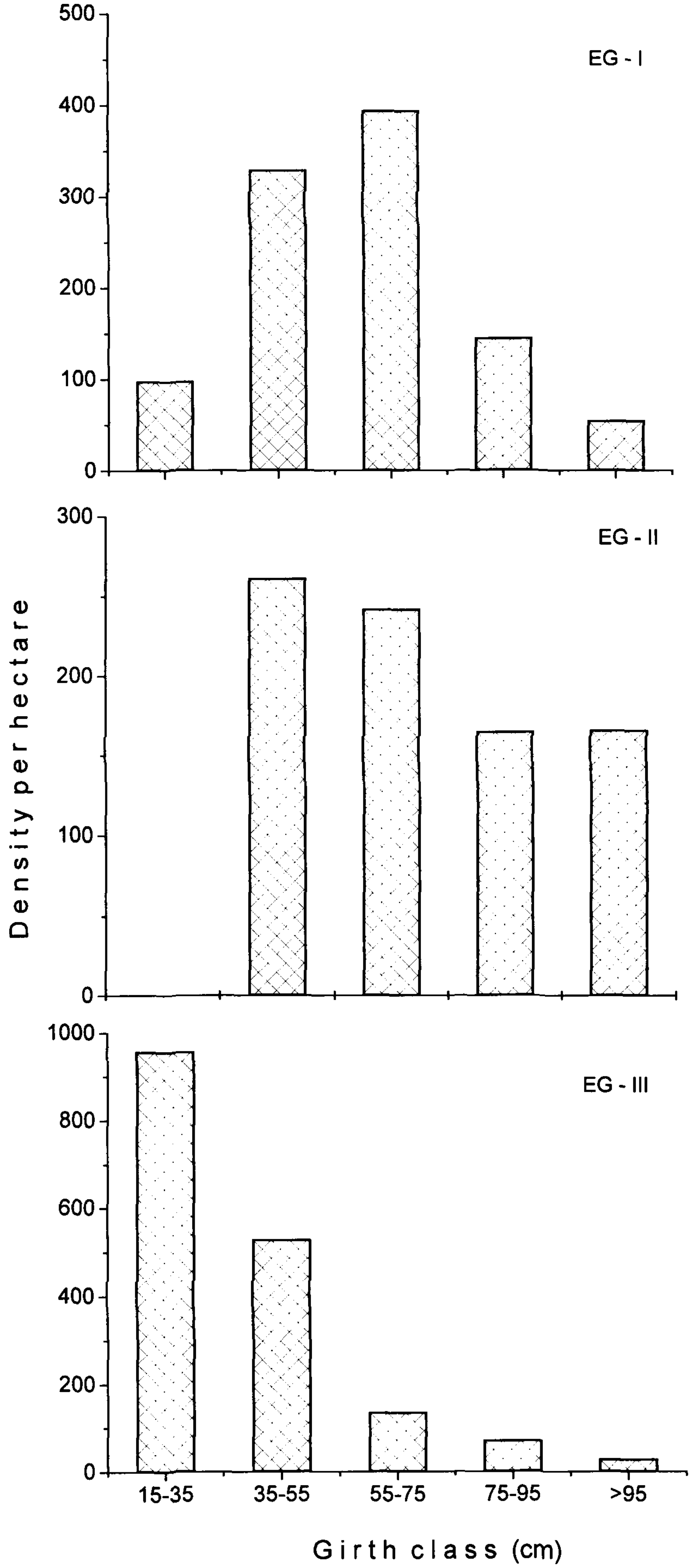


Fig. 5.7. Distribution of tree species in different girth clases in the three stands (EG - I, EG - II, EG - III) of the subtropical evergreen forest.

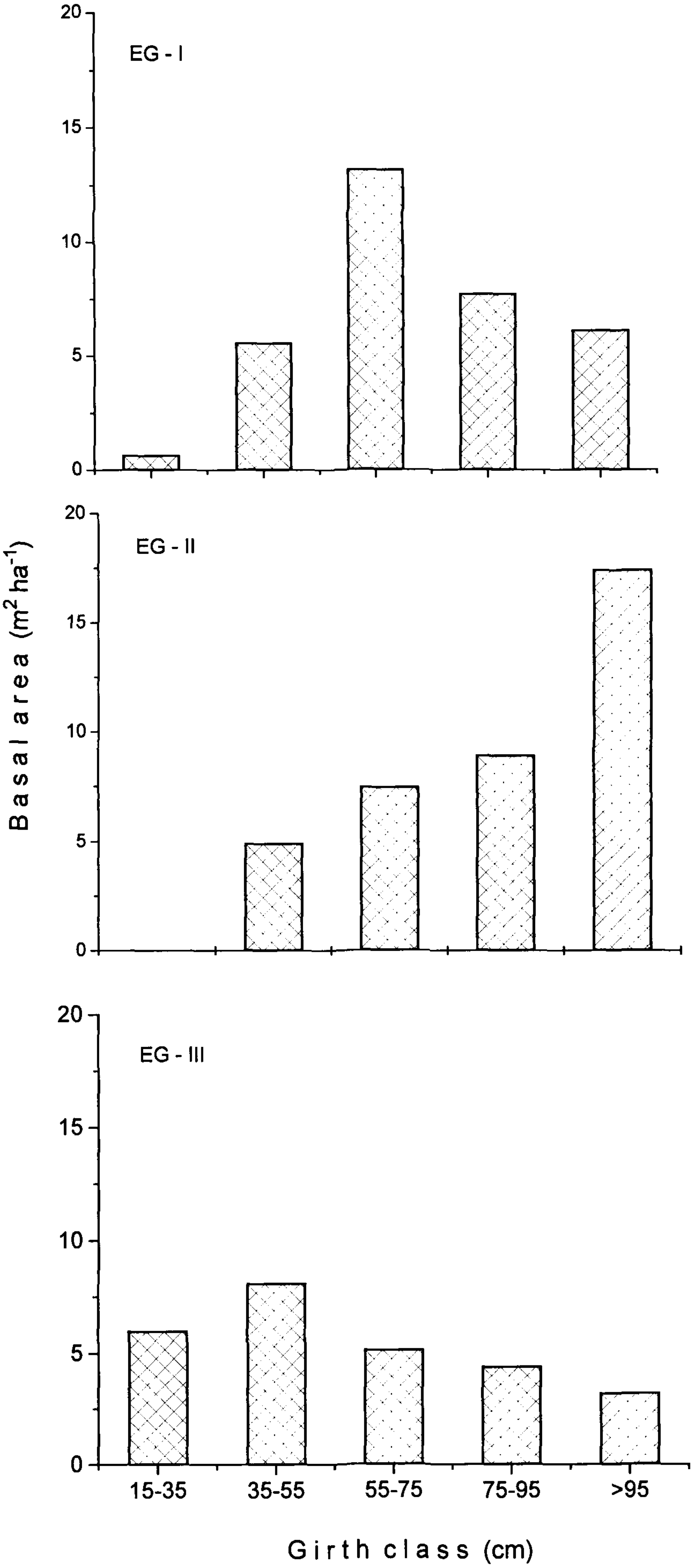


Fig. 5.8. Disribution of tree basal cover in different girth classes in the three stands (EG - I, EG - II, EG - III) of the subtropical evergreen forest.

(IVI: 6.7) were dominant in stand EG–II and *Rhus javanica* (IVI: 32.5), *Ficus elastica* (IVI: 17.3), *Saprosma ternatum* (IVI: 12.6), *Eurya japonica* (IVI: 6.2) and *E. acuminata* (IVI: 7.1) were dominant in stand EG–III (Table 5.1a, 5.2a, 5.3a).

Lasianthus hookeri, *Oriocnide integrifolia* and *Trevesia palmata* in EG-I, and *Sterculia roxburghii*, *Saurauria roxburghii* and *Villebrunea frutescens* in EG–II, and *Psychotria symplocifolia*, *Rhododendron arboreum* and *Garcinia lancifolia* in EG-III had low importance values.

Among the shrub species *Dracaena aungustifolia* (IVI: 24.5), *Rubus ellipticus* (IVI: 19.5), *Litsea salicifolia* (IVI: 17.6), *Viburnum coriaceum* (IVI: 17.6) and *Mussaenda corymbosa* (IVI: 15.3) in EG-I, *Randia wallichii* (IVI: 18.5), *Celastrus stylosus* (IVI: 17.4), *Acacia pennata* (IVI: 14.7), *Psychotria denticulata* (IVI: 13.8) and *Artidesma vulgaris* (IVI: 13.6) in EG–II, and *Eurya japonica* (IVI: 14.5), *Coffea khasiana* (IVI: 13.4), *Symplocos paniculata* (IVI: 12.1), *Goldfussia echinata* (IVI: 11.3) and *Casearia vareca* (IVI: 11.1) in EG–III were dominant (Table 5.1b, 5.2b, 5.3b).

Asplenium sp., *Gleichenia* sp., *Pothos scandens*, *Sellaginella* sp., *Davaeillia* sp., *Elatostemma rupestre*, *Hemiphragma hetrophyllum*, *Setaria palmifolia*, *Paedaria foetida* and *Senecio grifithii* were dominant among herbaceous species in all the three stands (Table 5.1c, 5.2c, 5.3c).

Dominance-distribution pattern among the tree species was similar in all the three stands *i.e.*, it showed log normal distribution pattern (Fig. 5.9), signifying high equitability and low dominance in the community.

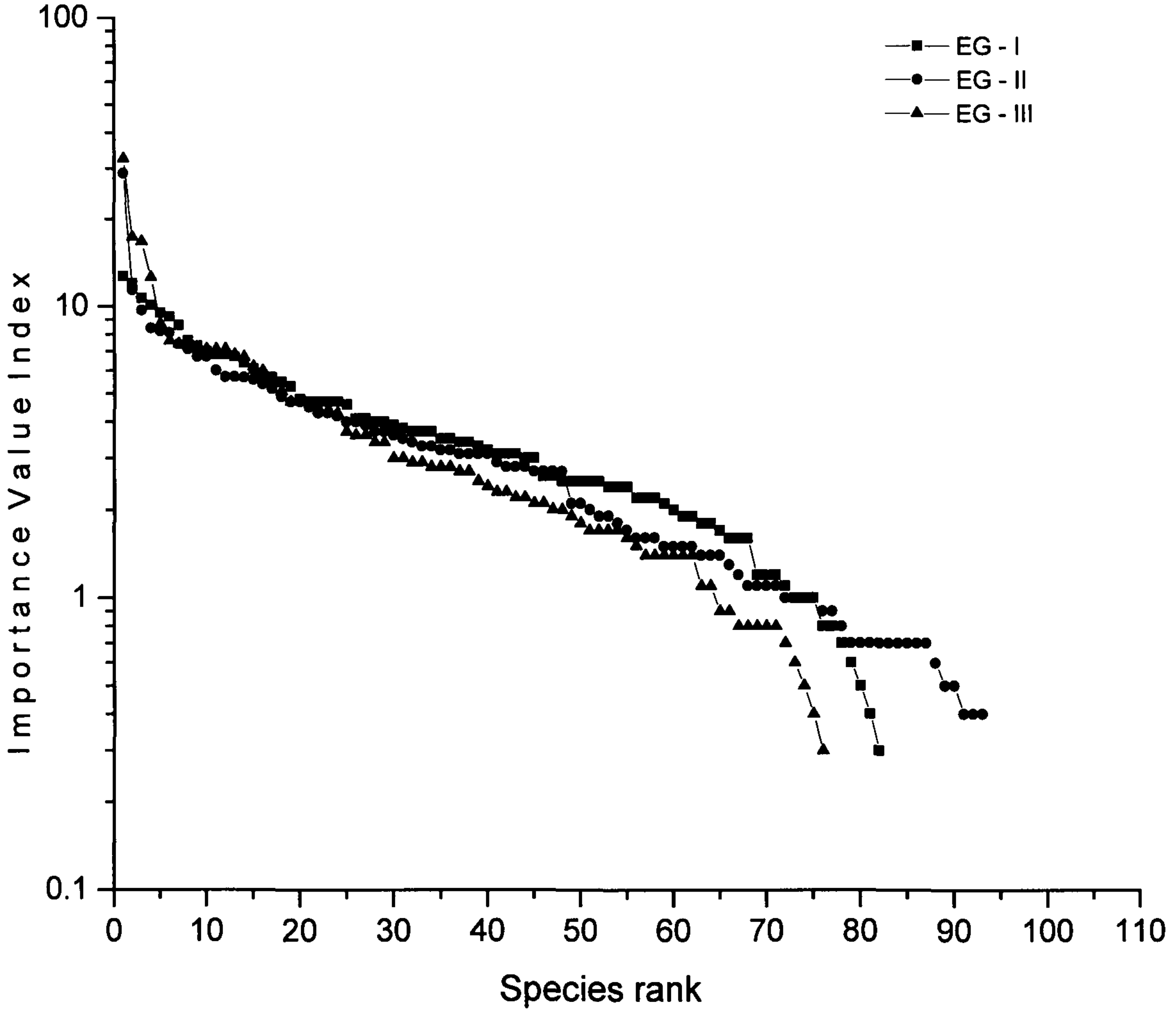


Fig. 5.9. Dominance -diversity curves of tree species (species names and their IVI are given in Table 5.1a, 5.2a, 5.3a) in the subtropical evergreen forest.

Similarity and diversity indices

Sorensen's index of similarity between the stands varied between 12.1% and 16.9% for tree species, 25.5% and 28.6% for shrub species, and from 7.8% to 37.9% for herbaceous species. Whittaker's β-diversity ranged from 0.67% to 0.80% for trees, 0.53% to 0.58% for shrubs, and 0.43% to 0.85% for herbaceous species. Low values of Sorensen's similarity index and high values of Whittaker's β-diversity index between the stands suggest marked difference in the species composition of the stands (Table 5.9).

Table. 5.9. Sorensen's similarity index (%) and Whittaker's β-diversity index (%) in the three subtropical evergreen forest stands.

Forest stands	Sorensen similarity index (%)			Whittaker β-diversity index		
	Trees	Shrubs	Herbs	Trees	Shrubs	Herbs
EG - I and II	16.9	26.4	7.8	0.80	0.58	0.85
EG- II and III	13.6	25.5	37.9	0.77	0.57	0.43
EG- III and I	12.1	28.6	8.2	0.67	0.53	0.83

Values of Shannon diversity index (3.57-4.32), Margalef species richness index (7.53-14.03) and Pielou evenness index (0.81-0.96) were high for tree species than the shrubs and herbs in all the three stands, while Simpson dominance index showed a reverse trend (Table 5.10).

Table. 5.10. Overall community characteristics of the subtropical evergreen forest stands.

Variables	Stands		
	EG-I	EG-II	EG–III
Trees			
Area sampled (ha)	1.2	1.2	1.2
Density ha^{-1}	1023 ±21	834 ±17	1723 ±15
Basal cover (m^2 ha^{-1})	33.3 ±0.59	38.8 ±2.22	27 ±1.14
Species richness	82	93	76
Number of genera	63	65	60
Number of families	36	39	33
Shannon diversity index	4.2	4.17	3.9
Margalef species richness index	11.7	13.7	10.07
Pielou evenness index	0.95	0.92	0.90
Simpson dominance index	0.02	0.02	0.03
Shrubs			
Area sampled (m^2)	750	750	750
Density ha^{-1}	1747 ±32	3023 ±102	2080 ±97
Species richness	20	23	27
Number of genera	18	22	26
Number of families	13	17	19
Shannon diversity index	2.77	2.97	3.19
Margalef species richness index	4.12	4.1	4.39
Pielou evenness index	0.93	0.95	0.97
Simpson dominance index	0.07	0.06	0.04
Herbs			
Area sampled (m^2)	120	120	120
Density per 100 m^2	1554 ±29	1523 ±46	1635 ±21
Species richness	44	35	47
Number of genera	38	34	40
Number of families	32	31	22
Shannon diversity index	3.4	3.16	3.44
Margalef species richness index	5.84	4.66	6.20
Pielou evenness index	0.90	0.82	0.89
Simpson dominance index	0.05	0.05	0.04

Population structure and regeneration of tree species

Density of tree seedling

Mean seedling density (plants 100 m^2) was 494 ±29 in EG–I, 959 ±46 in EG–II, and 1040 ±21 in EG–III. Seedlings of *Ostodes paniculata*, *Persea duthiei*, *Macaranga denticulata*, *Diospyros undulata* and *Engelhardtia spicata* were common in EG–I, while those of *Castanopsis kurzii*, *Citrus medica*, *Macaranga denticulata, Skimmia laureola* and *Persea duthiei* were common in EG–II. *Rhododendron arboreum*, *Exbucklandia populnea*, *Eurya acuminata*, *Scheffelera hypoleuca* and *Ficus oligodon* seedlings were common in EG–III. There were few seedlings of *Citrus hystrix*, *Echinocarpus murex* and *Elaeocarpus sikkimensis* in EG–I, *Cinnamomum tamala* and *Micromellum integrrimum* in EG–II, *Sapindus pinnata* and *Leptodermis griffithii* in EG–III (Table 5.11a, 5.11b, 5.11c).

Density of tree sapling

The mean sapling density was 3813 ±32, 4746 ±102 and 5085 ±97 plants ha^{-1} in EG–I, II, and III, respectively. The saplings of *Cinnamomum tamala*, *Bielshmiedia roxburghiana*, *Citrus medica*, *Glochidion assamicum* and *Callicarpa vestita* were common in stand EG–I, while those of *Albizia chinensis, Alchornea tiliaefolia*, *Bauhinia variegata*, *Callicarpa rubella* and *Callophyllum polyanthum* were common in stand EG–II, and *Symplocos racemosa*, *Rhododendron arboreum*, *Daphniphyllum himalayense, Exbucklandia populnea* and *Symplocos laurina* in EG–III. The species like *Sterculia hamiltonii*, *Taxus*

Table 5.11a. Frequency (%), density (plant 100m^2) and importance value index of tree seedlings (<5cm cbh) in stand I of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Callicarpa vestita Wall. ex. Cl.	Verbenaceae	31	19	11.9
Castanopsis indica A.DC.	Fagaceae	18	14	7.7
Castanopsis tribuloides (Sm.) DC.	Fagaceae	11	8	4.4
Citrus hystrix DC.	Rutaceae	4	3	1.6
Diospyros undulata DC.	Ebenaceae	40	29	16.7
Dysoxylum aliarium (Ham.) Balak.	Meliaceae	33	26	14.2
Echinocarpus murex Benth.	Elaeocarpaceae	7	6	3.1
Elaeocarpus sikkimensis Mast.	Elaeocarpaceae	9	7	3.8
Engelhardtia spicata (Wall.)	Juglandaceae	35	28	15.2
Ficus elastica Roxb. ex Horneum	Moraceae	8	4	2.7
Garcinia cowa Roxb. ex DC.	Clusiaceae	28	18	10.7
Ilex venulosa (Wall.) Hk. f.	Aquifoliaceae	18	14	7.9
Macaranga denticulata Wall.	Euphorbiaceae	48	30	18.7
Macropanax undulatus (Wall. ex D. Don.) Seem.	Araliaceae	21	9	6.9
Maesa tetrandra (Roxb.) DC.	Myrsinaceae	10	6	3.7
Micromelum integerrimum (Roxb.) Wt. & Arn.	Rutaceae	18	13	7.4
Olax acuminata Benth.	Oleaceae	26	20	11.1
Ostodes paniculata Bl.	Euphorbiaceae	65	43	26.0
Persea duthiei King. ex Hk. f.	Lauraceae	54	37	21.8
Vernonia arborea Buch.-Ham.	Asteraceae	12	7	4.3
		494		**200**

Table 5.11b. Frequency (%), density (plant 100m^2) and importance value index of tree seedlings in stand II of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Castanopsis kurzii (Hance.) Biswas	Fagaceae	98	70	21.0
Citrus medica Linn.	Rutaceae	60	56	14.9
Macaranga denticulata Wall. Arg.	Euphorbiaceae	65	43	13.5
Skimmia laureola (DC.) Sieb. & Zucc. ex Walp.	Rutaceae	57	41	12.3
Persea duthiei King ex Hk.f.	Lauraceae	58	40	12.2
Castanopsis indica A. DC.	Fagaceae	49	32	10.0
Cleidion spiciflorum (Burm.) Ham.	Euphorbiaceae	40	29	8.7
Calophyllum polyanthum Choisy	Euphorbiaceae	41	26	8.3
Dillenia indica Linn.	Dilleniaceae	34	24	7.3
Acacia pruinensis Kurz.	Mimosaceae	33	22	6.8
Antidesma acuminatum Wall. ex Wt.	Euphorbiaceae	26	23	6.3
Euonymus attenuatus Laws.	Celastraceae	31	19	6.2
Derris robusta (Roxb. ex DC.) Benth.	Fabaceae	28	18	5.6
Dimocarpus longan Lour.	Sapindaceae	24	19	5.5
Elaeocarpus sikkimensis Mast.	Elaeocarpaceae	24	17	5.1
Albizia chinensis Osb.	Mimosaceae	27	13	4.7
Camellia caudata Wall.	Theaceae	22	16	4.7
Ficus elastica Roxb. ex Horneum	Moraceae	22	16	4.7
Echinocarpus murex Benth.	Elaeocarpaceae	22	14	4.5
Vatica lanceaefolia Bl.	Sapindaceae	19	13	4.1
Diospyros stricta Roxb.	Ebenaceae	23	9	3.8
Diospyros undulata DC.	Ebenaceae	18	13	3.8
Garcinia cowa Roxb. ex DC.	Clusiaceae	21	9	3.6
Callicarpa rubella Lindl.	Verbenaceae	19	9	3.4
Caryota urens Linn.	Arecaceae	14	13	3.4
Ilex venulosa (Wall.) Hk. f.	Aquifoliaceae	18	7	2.9
Dysoxylum aliarium (Ham.) Balak.	Meliaceae	16	7	2.7
Macropanax undulatus (Wall. ex D. Don) Seem.	Araliaceae	14	8	2.6
Maesa tetrandra (Roxb) DC.	Myrsinaceae	10	6	1.9
Vernonia arborea Buch.-Ham.	Asteraceae	7	4	1.3
Olax acuminata Benth.	Oleaceae	8	3	1.3
Saprosma ternatum Hk. f.	Rubiaceae	7	3	1.1
Cinnamomum tamala Fr. Nees	Lauraceae	6	3	1.0
Micromelum integerrimum (Roxb.) Wt. & Arn.	Rutaceae	4	2	0.7
		959		**200**

Table 5.11c. Frequency (%), density (plant 100m^2) and importance value index of tree seedlings in stand III of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Rhododendron arboreum Smith.	Ericaceae	128	77	23.5
Exbucklandia populnea (R. Br. ex Griff.) R.W.Br.	Hamamelidaceae	104	68	20.0
Eurya acuminata DC.	Theaceae	73	63	16.1
Schefflera hypoleuca Kurz.	Araliaceae	47	38	10.0
Glochidion khasicum Hk. f.	Euphorbiaceae	44	38	9.7
Ficus oligodon Miq.	Moraceae	48	30	9.0
Glochidion acuminatum Muell.-Arg.	Euphorbiaceae	39	32	8.4
Elaeocarpus sikkimensis Mast.	Elaeocarpaceae	43	28	8.3
Cinnamomum tamala Fr. Nees.	Lauraceae	38	28	7.7
Casearia vareca Roxb.	Flacourtiaceae	29	18	5.5
Wendlandia paniculata DC.	Rubiaceae	26	19	5.3
Aporusa aurea Hk. f.	Euphorbiaceae	27	18	5.1
Echinocarpus murex Benth.	Elaeocarpaceae	24	18	5.0
Daphne involucrata Wall.	Thymeliaceae	24	17	4.8
Echinocarpus dasycarpus Benth.	Elaeocarpaceae	27	14	4.6
Cinnamomum pauciflorum Nees.	Lauraceae	24	12	4.0
Garcinia cowa Roxb.	Clusiaceae	18	14	3.8
Saprosma tetrasperma Roxb.	Rubiaceae	21	11	3.6
Macropanax undulatus (Wall.ex D. Don.) Seem.	Araliaceae	20	11	3.5
Schima wallichii (DC.) Korth.	Theaceae	20	9	3.3
Carryota urens Linn.	Arecaceae	16	11	3.1
Elaeocarpus rugosus Roxb.	Elaeocarpaceae	15	11	3.0
Pyrus pashia D. Don.	Rosaceae	14	10	2.8
Ilex odorata D. Don.	Aquifoliaceae	14	9	2.7
Helicia nilagirica Bedd.	Proteaceae	15	8	2.5
Picrasma javanica Bl.	Simaroubaceae	13	8	2.3
Photinia notoniana W. & A.	Rosaceae	13	7	2.3
Diospyros pilosula (DC.) Hiem.	Ebenaceae	12	8	2.2
Euonymous lawsonii Cl. & Pr.	Celastraceae	12	8	2.2
Viburnum simonsii Hk. f. & Th.	Caprifoliaceae	14	6	2.2
Litsea cubeba Lour.	Lauraceae	11	8	2.1
Beilshmiedia roxburghiana Nees.	Lauraceae	14	4	2.0
Camellia caduca Brandis	Theaceae	11	6	1.9
Actinidia callosa Lindl.	Actinidiaceae	11	5	1.8
Euonymus attenuatus Laws.	Celastraceae	7	3	1.1
Ligustrum robustum (Roxb.) Bl.	Oleaceae	4	3	0.8
Olax acuminata Benth.	Oleaceae	4	3	0.8
Ilex embelioides Hk. f.	Aquifoliaceae	4	2	0.6
Lyonia ovalifolia (wall.) Druce.	Ericaceae	4	2	0.6
Myrica esculenta Buch.-Ham. ex D. Don	Myricaceae	3	2	0.6
Pyrus sp.	Rosaceae	3	2	0.5
Sapindus pinnata (Linn. f.) Kurz.	Anacardiaceae	3	1	0.4
Leptodermis griffithii Hk. f.	Rubiaceae	2	1	0.3
		1040		**200**

baccata and *Turpinia pomifera* in EG–I, *Dysoxylum binectariferum* and *Vatica lanceaefolia* in EG–II, and *Premna racemosa*, *Calophllum polyanthum* and *Litsea khasyana* in EG–III had low sapling density (Table 5.12a, 5.12b, 5.12c).

Density of adult trees

The mean density of adult (>15cm cbh) trees was 1023 ±21, 834 ±17 and 1723 ±15 individuals ha^{-1} in stand EG–I, II and III, respectively (Table 5.8).

The overall population density of seedlings, saplings and adult trees formed a pyramidal structure in all the three stands. Preponderance of tree seedlings, followed by a steep decline in population density of saplings and adult trees indicated that the period between seedling to sapling stage was the most critical stage in the life cycle of the tree population, as the maximum mortality occurred during this period (Fig. 5.10).

Population structure of dominant species

Ten dominant species in each of the three stands were selected on the basis of density to study their population structure. The density of tree seedlings and saplings, and of adult trees (>15 cm cbh) in different girth classes were determined to study the population structure of these tree species.

In stand EG–I plants of *Castanopsis indica*, *C. tribuloides*, *Citrus hystrix*, *Callicarpa vestita* and *Engelhardtia spicata* were present in most of the girth classes. However, individuals of *Bridellia retusa* (<5 cm cbh) *Garcinia lanceolata*, *Saprosma ternatum* (5-15 cm cbh) and *Ardisia crispa*, (<35 cm cbh) were absent. In *Persea gamblei,* although maximum number of plants was

Table 5.12a. Frequency (%), density (individuals ha^{-1}) and importance value index of tree saplings in stand I of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Cinnamomum tamala Fr. Nees.	Lauraceae	18	47	13.3
Beilshmiedia roxburghiana Nees.	Lauraceae	14	40	10.9
Citrus medica Linn.	Rutaceae	14	40	10.9
Glochidion assamicum Hk. f.	Euphorbiaceae	13	30	9.0
Callicarpa vestita Wall. ex Cl.	Verbenaceae	13	27	8.5
Albizia chinensis Osb.	Mimosaceae	11	30	8.3
Lindera caudata Benth.	Lauraceae	11	30	8.3
Callicarpa rubella Lindl.	Verbenaceae	12	20	7.2
Calophyllum polyanthum Choisy	Clusiaceae	9	23	6.6
Helicia excelsa Bl.	Proteaceae	9	23	6.6
Fissistigma verrucosum (Hk.f. & Th.) Merr.	Annonaceae	8	23	6.3
Pteracanthus griffithianus Nees.	Acanthaceae	9	20	6.1
Engelhardtia spicata (Wall.) Kds. & Val.	Juglandaceae	9	17	5.6
Capparis acutifolia Sm.	Capparidaceae	7	20	5.4
Schima wallichii (DC.) Korth.	Theaceae	7	20	5.4
Syzygium cuminii (Linn.) Skeels	Myrtaceae	8	13	4.8
Beilshmiedia assamica Meissn.	Lauraceae	6	17	4.6
Litsea laeta Wall. ex Nees.	Lauraceae	6	17	4.6
Garcinia lancifolia (G. Don) Roxb.	Clusiaceae	7	13	4.4
Macaranga indica Wt.	Euphorbiaceae	7	13	4.4
Syzygium tetragonum (Wt.) Kurz.	Myrtaceae	7	13	4.4
Euonymus lawsonii Cl. & Pr.	Celastraceae	8	10	4.3
Elaeocarpus lancifolius Roxb.	Elaeocarpaceae	6	13	4.1
Ficus nervosa Heyne. ex Roth.	Moraceae	5	13	3.7
Cleidion spiciflorum Burm.	Euphorbiaceae	5	10	3.2
Kydia calycina Roxb.	Malvaceae	5	10	3.2
Saurauia nepaulensis DC.	Saurauiaceae	5	10	3.2
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	3	10	2.5
Caryota urens Linn.	Arecaceae	4	7	2.4
Helicia nilagirica Bedd.	Proteaceae	4	7	2.4
Sarcosperma griffithii Cl.	Sapotaceae	4	7	2.4
Garcinia pedunculata G. Don.	Clusiaceae	2	10	2.2
Castanopsis indica A. DC.	Fagaceae	3	7	2.0
Lindera latifolia Hk. f.	Lauraceae	3	7	2.0
Litsea cubeba (Lour.) Pers.	Lauraceae	3	7	2.0
Castanopsis tribuloides (Sm.) DC.	Fagaceae	3	7	2.0
Eurya acuminata DC.	Theaceae	2	7	1.7
Trevesia palmata (Roxb.) Vis.	Araliaceae	2	7	1.7
Casearia zeylanica (Gaert.) Thw.	Flacourtiaceae	3	3	1.5
Glycosmis arborea (Roxb.) DC.	Rutaceae	3	3	1.5
Castanopsis indica A. DC.	Fagaceae	2	3	1.2
Camellia caudata Wall.	Theaceae	2	3	1.2
Citrus hystrix DC.	Rutaceae	1	3	0.8
Sterculia hamiltonii (O. ktz.) Adelb.	Sterculiaceae	1	3	0.8
Taxus baccata Linn.	Taxaceae	1	3	0.8
Turpinia pomifera (Roxb.) DC.	Sapindaceae	1	3	0.8
		286		**200**

Table 5.12b. Frequency (%), density (individuals ha^{-1}) and importance value index of tree saplings in stand II of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Albizia chinensis Osb.	Mimosaceae	22	63	8.7
Alchornea tiliaefolia Muell.-Arg.	Euphorbiaceae	7	13	2.2
Bauhinia variegata Linn.	Cesalpiniaceae	21	60	8.2
Callicarpa rubella Lindl.	Verbenaceae	6	7	1.5
Calophyllum polyanthum Choisy	Euphorbiaceae	14	30	4.7
Camellia caudata Wall.	Theaceae	18	23	4.8
Caryota urens Linn.	Arecaceae	10	13	2.7
Castanopsis indica A. DC.	Fagaceae	14	20	3.9
Castanopsis kurzii (Hance.) Biswas	Fagaceae	17	27	4.9
Cinnamomum tamala Fr. Nees.	Lauraceae	4	7	1.2
Citrus hystrix DC.	Rutaceae	37	83	12.7
Citrus medica Linn.	Rutaceae	18	27	5.0
Cleidion spiciflorum Burm.	Euphorbiaceae	7	10	1.9
Derris robusta (Roxb. ex DC.) Benth.	Fabaceae	14	30	4.7
Diospyros undulata Kurz.	Ebenaceae	11	20	3.4
Duabanga grandiflora (Roxb. ex DC.) Walp.	Sonneratiaceae	11	23	3.7
Dysoxylum binectariferum Hk. f. et Bedd.	Meliaceae	2	7	0.9
Dysoxylum gobara (Buch.-Ham.) Merr.	Meliaceae	12	17	3.3
Echinocarpus murex Benth.	Elaeocarpaceae	12	27	4.1
Elaeocarpus lancifolius Roxb.	Elaeocarpaceae	9	23	3.3
Ficus elastica Roxb.	Moraceae	11	27	3.9
Ficus oligodon Miq.	Moraceae	38	50	10.1
Glochidion oblatum Hk. f.	Euphorbiaceae	21	63	8.5
Glycosmis arborea (Roxb.) DC.	Rutaceae	42	83	13.5
Helicia nilagirica Bedd.	Proteaceae	12	17	3.3
Kydia calycina Roxb.	Malvaceae	16	20	4.2
Lindera caudata Benth.	Lauraceae	33	57	9.9
Litsea laeta Wall. ex Nees.	Lauraceae	16	37	5.5
Macaranga denticulata Muell.-Arg.	Euphorbiaceae	13	27	4.2
Macropanax undulatus (Wall ex D. Don.) Seem.	Araliaceae	6	13	2.0
Mallotus philippensis (Lam.) Muell.-Arg.	Euphorbiaceae	32	57	9.7
Micromellum integerrimum (Roxb.) Wt. & Arn.	Rutaceae	7	10	1.9
Oricnide integrifolia Gaud.	Urticaceae	4	7	1.2
Ostodes paniculata Bl.	Euphorbiaceae	12	23	3.8
Prunus nepaulensis (Ser.) Steud.	Rosaceae	8	17	2.6
Saprosma ternatum Hk. f.	Rubiaceae	9	10	2.2
Saurauia nepaulensis DC.	Saurauiaceae	8	17	2.6
Schima wallichii (DC.) Korth.	Theaceae	6	13	2.0
Symplocos spicata Roxb.	Symplocaceae	5	10	1.6
Syzygium cumini (Linn.) Skeels	Myrtaceae	17	47	6.5
Syzygium formosum Wall.	Myrtaceae	7	17	2.5
Talauma hodgsonii Hk. f. & Th.	Magnoliaceae	15	20	4.0
Terminalia bellerica (Gaertn) Roxb.	Combretaceae	8	17	2.6
Tetrameles nudiflora R. Br.	Tetrameliaceae	3	7	1.0
Vatica lanceaefolia Bl.	Sapindaceae	2	3	0.6
		629		**200**

Table 5.12c. Frequency (%), density (individuals ha^{-1}) and importance value index of tree saplings in stand III of the evergreen forest.

Name of species	Family	Density	Frequency	IVI
Symplocos racemosa Roxb.	Symplocaceae	51	90	14.3
Rhododendron arboreum Smith.	Ericaceae	43	100	13.8
Daphniphyllum himalayense (Benth.) Muell.-Arg.	Daphniphyllaceae	35	93	12.1
Exbucklandia populnea R. Br.ex Griff.	Hamamelidaceae	50	43	10.7
Symplocos laurina (Reitz.) Wall.	Symplocaceae	36	50	9.1
Eurya acuminata DC.	Theaceae	28	57	8.4
Myrica esculenta Buch-Ham ex D.Don	Myricaceae	25	53	7.7
Schima wallichii (DC.) Korth.	Theaceae	23	57	7.6
Saprosma ternatum Hk.f.	Rubiaceae	26	47	7.3
Engelhardtia spicata Leschen ex Bl.	Juglandaceae	24	50	7.3
Zanthoxylum armatum DC.	Rutaceae	19	57	7.0
Wendlandia paniculata DC.	Rubiaceae	21	47	6.6
Carpinus viminea Lindl.	Corylaceae	17	43	5.7
Persea duthiei King ex Hk.f.	Lauraceae	17	43	5.7
Antidesma acidum Reitz.	Euphorbiaceae	18	40	5.7
Kydia calycina Roxb.	Malvaceae	18	40	5.7
Photinia polycarpa (Hk.f.) Balakr.	Rosaceae	19	37	5.6
Glochidion khasicum Hk.f.	Euphorbiaceae	16	40	5.3
Beilshmiedia roxburghiana Nees.	Lauraceae	20	27	5.0
Echinocarpus murex Benth.	Elaeocarpaceae	13	40	4.9
Dimocarpus longan Lour.	Sapindaceae	13	37	4.6
Lyonia ovalifolia (Wall) Druce	Ericaceae	15	30	4.5
Cleidion spiciflorum (Burm.) Merr.	Euphorbiaceae	10	23	3.2
Helicia nilagirica Bedd.	Proteaceae	9	23	3.1
Spondias pinnata (Linn.f) Kurz.	Anacardiaceae	9	23	3.1
Ilex odorata D. Don.	Aquifoliaceae	9	20	2.8
Olea dioica Roxb.	Oleaceae	9	20	2.8
Ilex embelioides Hk.f.	Aquifoliaceae	7	23	2.8
Drypetes assamica Hk.f.	Euphorbiaceae	9	17	2.6
Ficus nervosa Heyne. ex Roth.	Moraceae	8	17	2.4
Salix tetrasperma Roxb.	Salicaceae	7	10	1.8
Litsea cubeba Lour.	Lauraceae	5	10	1.5
Ulmus lanceifolia Roxb.	Ulmaceae	5	10	1.5
Garcinia pedunculata G. Don.	Clusiaceae	4	10	1.3
Polyalthia simiarum Hk.f. & Th.	Annonaceae	4	10	1.3
Glochidion acuminatum Muell.-Arg.	Euphorbiaceae	5	7	1.2
Schefflera glomerata Cl.	Araliaceae	5	7	1.2
Callophyllum polyanthum Choisy	Euphorbiaceae	3	7	0.9
Premna racemosa Wall.	Verbenaceae	3	7	0.9
Litsea khasyana Meissn.	Lauraceae	3	3	0.7
		661		**200**

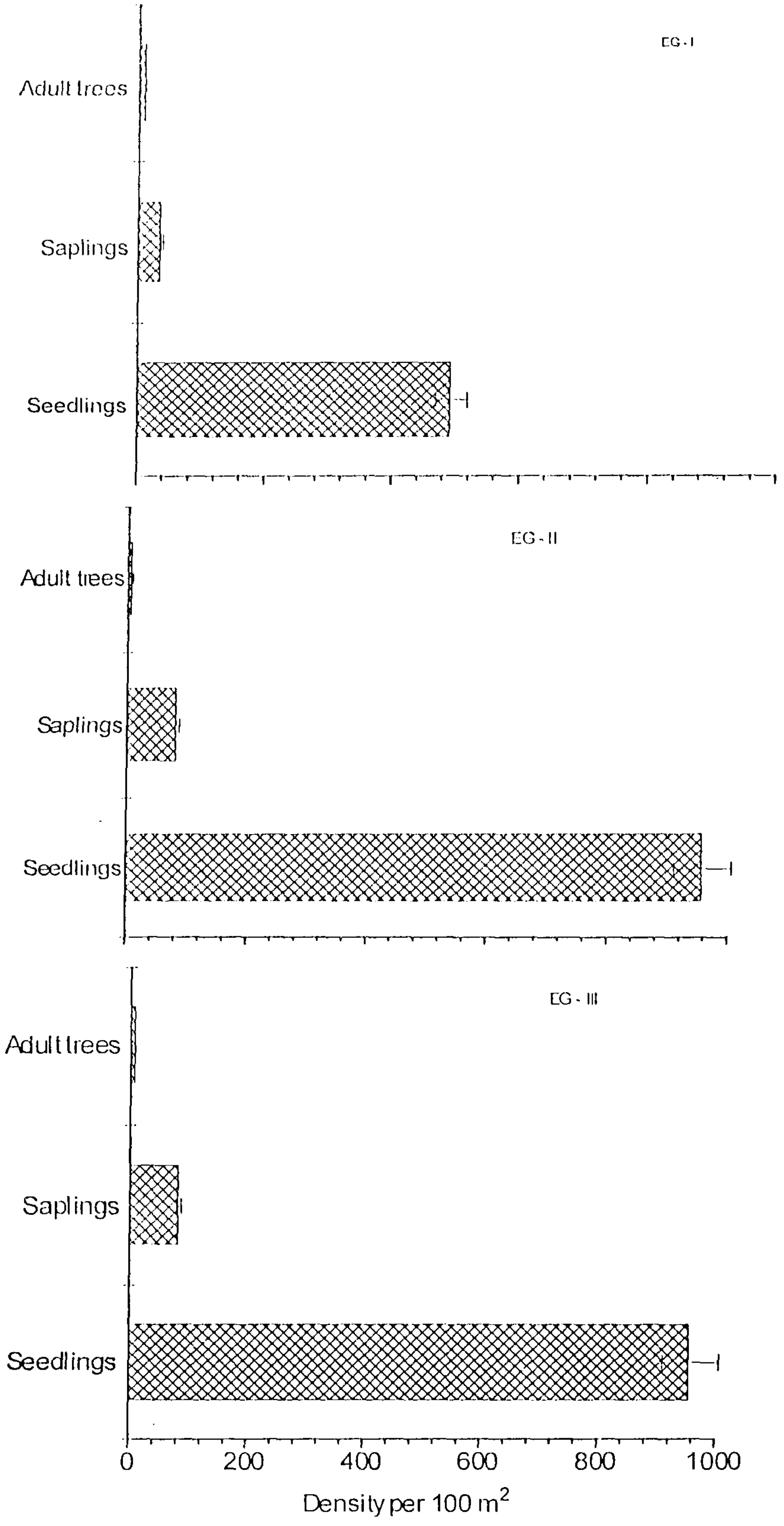


Fig. 5.10 Population density of seedlings, saplings and adult trees in the three stands of evergreen forest.

recorded in <5 cm girth class, there was no individual in 5-15 cm girth class (Fig. 5. 11a).

In stand EG–II individuals of all the girth classes were present in almost all species except in *Symplocos paniculata* where the girth class <5 cm cbh remained unrepresented. In case of *Persea duthiei* girth class 5-15 cm cbh was absent (Fig. 5.11b). In EG–III plants of *Ficus elastica*, *Saprosma ternatum*, *Eurya japonica*, *E. acuminata* and *Bielshmiedia roxburghii* were present in almost all girth classes, however, young plants (up to 15 cm cbh) of *Rhus javanica*, *Vitex vestita*, *Neolitsea pallens* were absent from the stand. *Ixora parviflora* and *Diospyros pilosula* showed maximum density in <5 cm girth class, but in 5-15 cm girth class there was no plant (Fig. 5.11c).

The girth-class distribution pattern in the dominant species revealed that the population structure in most of the species was upright pyramidal, with large number of young (<15 cm cbh) individuals in their populations.

Discussion

The two stands of evergreen forest, *i.e.*, EG-I (Nokrek Biosphere Reserve, buffer area) and EG- II (Nokrek Biosphere Reserve, core area) are located in the south western part of the state (Garo hills) at an altitude of 1000-1400m; the stand EG-I located in the buffer zone of the Nokrek Biosphere Reserve was disturbed while that in the core zone (EG-II) was well preserved. The stand EG-III (Swer sacred grove) is situated at an altitude of about 2000m in the East Khasi hills of the state. The Stand EG-III, being a sacred forest was also well protected. The distance between the stands at Garo hills and Khasi

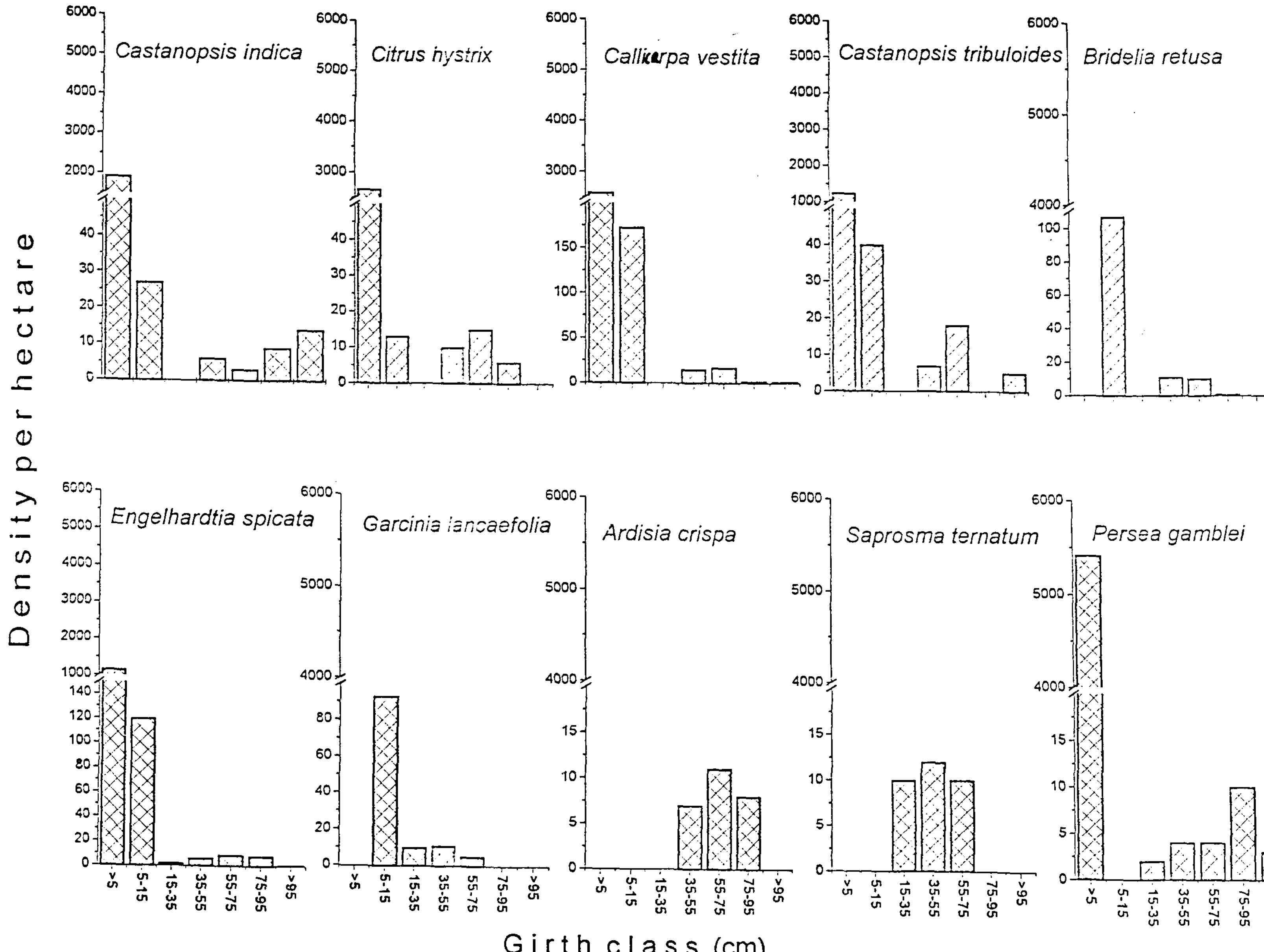


Fig.5.11a. Population structure of ten dominant species in subtropical forest stand (EG - I).

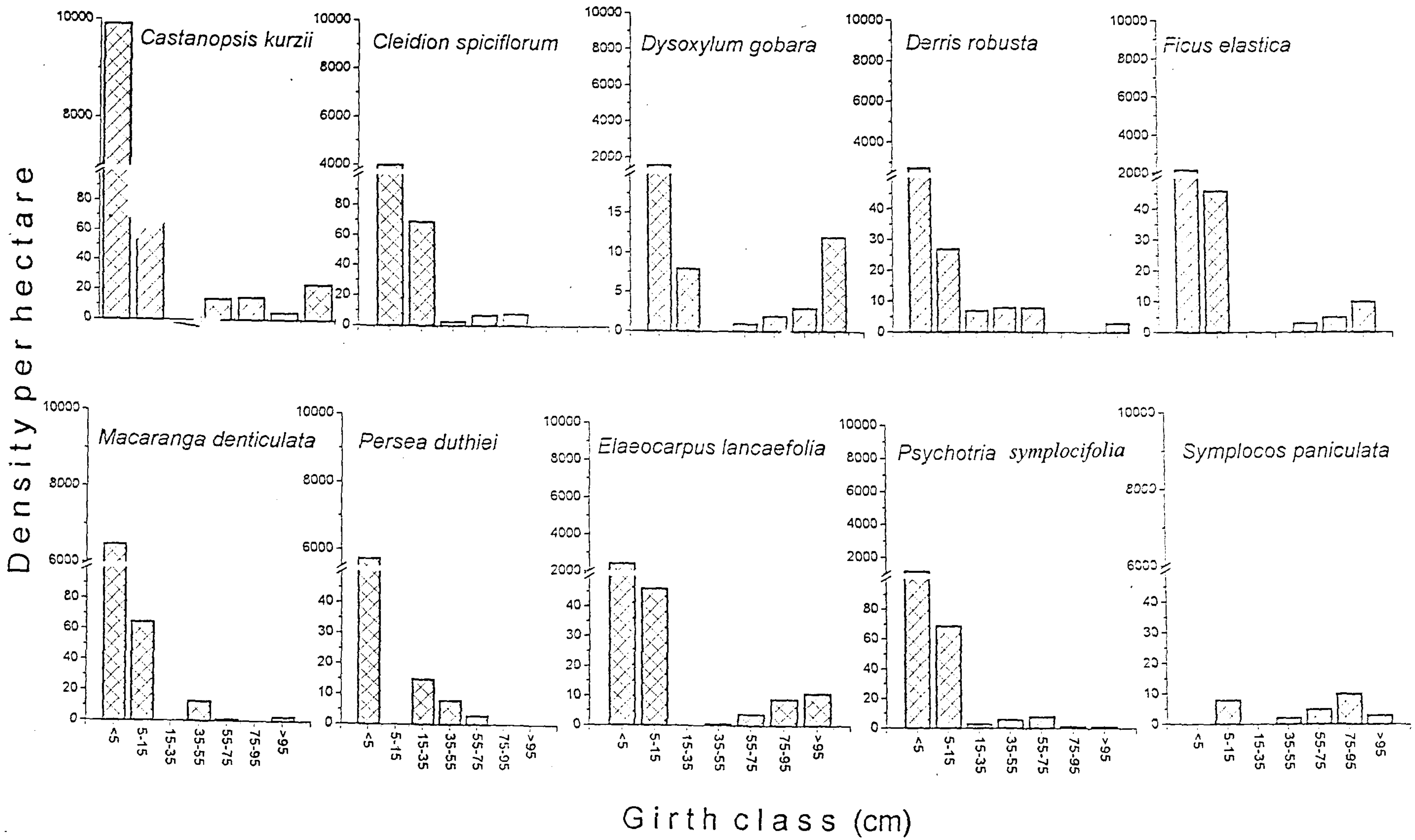


Fig. 5.11 b. Population structure of ten dominant species in subtropical evergreen forest stand (EG - II).

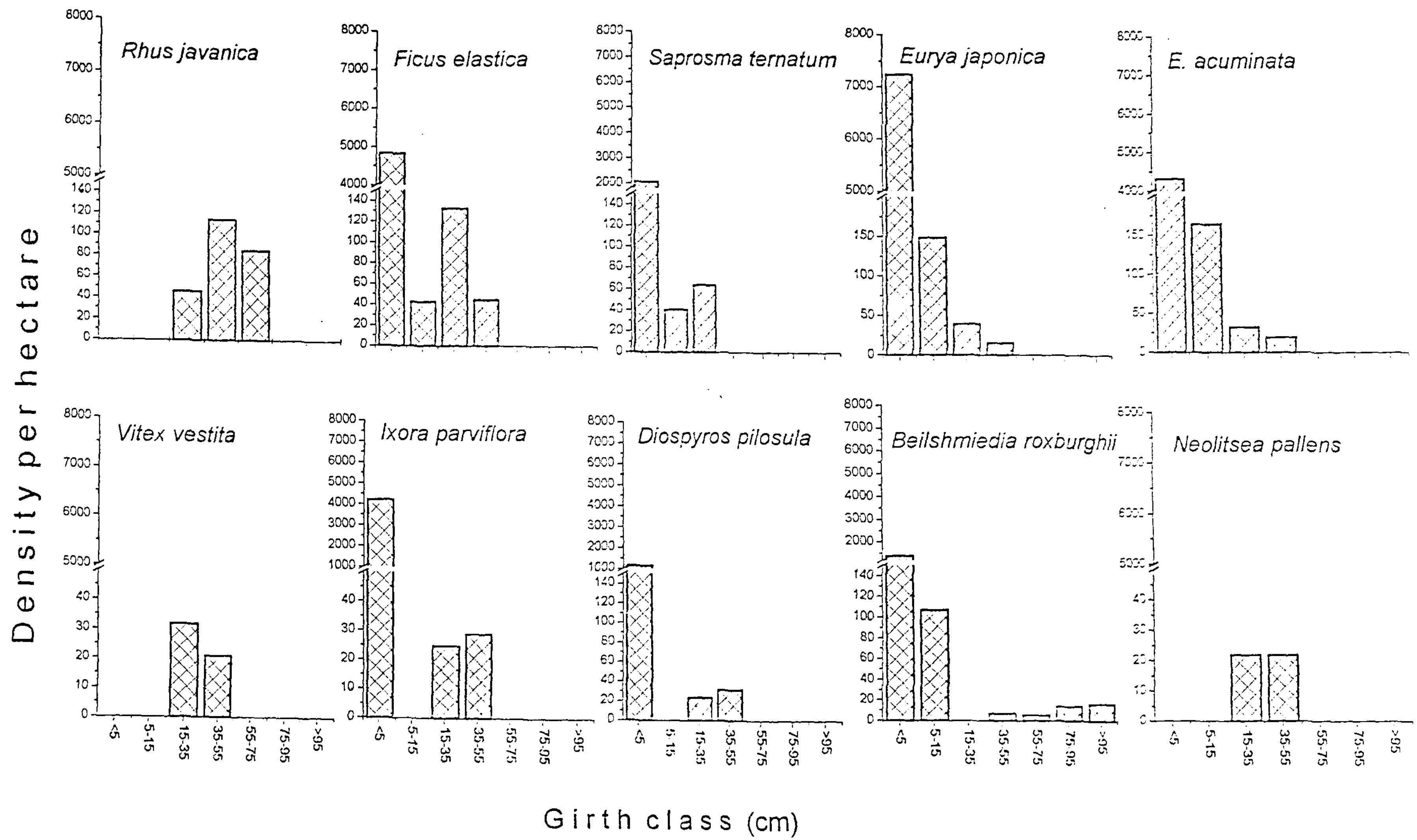


Fig.5.11c. Population structure of ten dominant species in subtropical evergreen forest stand (EG - III).

hills is about 400Km. In Garo hills the annual rainfall and mean monthly maximum and minimum temperatures were higher than the Swer, where climatic conditions are similar to Upper Shillong (Fig. 2.1). Relative humidity, on the contrary, was always higher at Upper Shillong due to low temperature. Therefore, the differences in the floristic composition and community characteristics observed in the three stands could be attributed to the climatic condition and the disturbance.

Low similarity and high β-diversity index between the two stands of the Nokrek Biosphere Reserve was mainly due to disturbance, while difference between the Nokrek stands (EG-I & EG-II) and Swer stand (EG-I) could be attributed to the variation in climatic condition. The evergreen forest stands in the Garo hills and Khasi hills also differed in respect of dominant tree species. In the former *Castanopsis indica*, *C. kurzii*, *Macaranga indica* and *Elaeocarpus lancaefolius* were dominant species, while in the later *Rhus javanica*, *Ficus elastica*, *Beilshmiedia roxburghiana* and *Saprosma ternatum* were dominant. On the basis of families' dominance, present forest stands were close to Pasoh reserve forest (Manokaran *et al.* 1991), tropical forest of Sierra de Manantlam (Vazquez and Givnish 1998) and tropical evergreen forest of Western Ghats (Ayyappan 2002) where Lauraceae, Moraceae, Euphorbiaceae and Rubiaceae are reported to be the dominant families.

Tree growth was better in stand EG-I and II as large number of big trees (>95 cm cbh) were present in these stands as compared to the stand EG-III, where individuals of lower girth (15-35 cm cbh) class were abundant (*ca.* 56% of the total stand density).

Gentry (1988) have reported 606 individuals representing 300 trees from 1-hectare area and Valencia *et al.* (1994) have reported 1561 individuals representing 473 tree (> 5 cm dbh) species from 1-hectare area of Amazonian forest. Compared to these values tree species (75-93 species) richness of present study sites is very low. However, the values are comparable with those of Bunyavezchewin (1999) from seasonal dry evergreen forest of Thailand (76-100 species from 1 ha) and Felfili and Maria (1995) from Gamma gallery forest (87 species from 1 ha).

Majority of species in all the three stands had low frequency and showed contagious/clumped distribution therefore, making the community highly heterogeneous and patchy. Several factors contribute to the clumped distribution of species, notable among them are insufficient mode of seed dispersal (Richards 1996) and formation of gaps due to natural disturbance (Armesto *et al.* 1986).

The stand density of tree species in stand EG-III was comparatively higher (1723 ±15 stem ha^{-1}) than stand EG-I and stand EG-II (834 ±17 - 1023 ±21 stem ha^{-1}) primarily due to presence of large number of young individuals (about 56% of total stand density) in the stand. The tree density at the present study sites is comparable to the values reported by Aiba and Kitayama (1999) from tropical rain forest of Mt. Kinabalu, Borneo (1730 stem ha^{-1}), *Valencia et al.* (1994) from Amazonian forest (1561 stem ha^{-1}), Pelissier and Riera (1993) from

French Guyana (1168 stem ha^{-1}), Strasberg (1996) from tropical rainforest, France (1079 stem ha^{-1}), Parthasarathy and Karthikeyan (1997) from Thirumanikkuzhi tropical evergreen forest, Western Ghats (974 stem ha^{-1}), Bunyavezchewin (1999) from seasonal dry evergreen forest, Thailand (1168 stem ha^{-1}), and Upadhyaya *et al.* (2002) from subtropical evergreen forest, Jaintia hills (938-1476 stem ha^{-1}).

The tree basal cover is comparable with the results of Campbell *et al.* (1986) from Terrafirme (27.6-32 m^2 ha^{-1}), Campbell *et al.* (1992) from Brazilian Amazon (25.5-27 m^2 ha^{-1}), Valencia *et al.* (1994) from Amazonian rainforest (29.1 m^2 ha^{-1}), Pascal and Pelissier (1996) from tropical evergreen forest, Uppangala (39.7 m^2 ha^{-1}), and Bunyavejchewin (1999) from seasonal dry evergreen forest of Thailand (29.1 m^2 ha^{-1}). The undisturbed stand EG-II had higher basal cover than the disturbed stand EG-I and moderately disturbed stand (EG-I), primarily due to presence of large old trees in the stand.

The lognormal dominance-distribution curves, as found in three stands of present study, signify equitability and stability of the community (Magurran 1988). It also indicates the maturity and complexity of natural community.

Tree regeneration was better in stand EG-I and EG- II as evident by large population of young individuals, while poor seedling density or in some cases their complete absence in EG-III was the reflection of the unfavourable regeneration condition in this stand. Poor regeneration in stand EG-III could be attributed mainly to the dense over-storey that significantly reduces the light intensity on the forest floor (810 lux or 13% of the outside forest). Tree regeneration in undisturbed humid forests is dependent upon the response of the seedlings and saplings to the forest microenvironment, frequency of favourable micro-sites (Barik *et al.* 1992, Jamir 2000), competition and interactive influence of an array of biotic and abiotic factors. Presence of thick layer of litter also acts as a mechanical barrier for seedling emergence, through release of allelochemics (Tripathi and Khan 1992).

Majority of the species was represented by all girth classes except above tree species in all the three stands. Low population density of young individuals of *Garcinia lancaefolia* and *Bridelia retusa* in stand EG-I, *Symplocos paniculata* in stand EG- II and *Rhus javanica*, *Vitex vestita* and *Neolitsea pallens* in the EG- III show their poor regeneration in these stands. Although it is difficult to pin point the factors responsible for poor regeneration of certain tree species, cattle grazing and collection of fuelwood in EG-I and EG-II and low light intensity seem to play important role for their poor regeneration.

CHAPTER VI

Community Structure of Subtropical Semi-evergreen forest

Subtropical forests are diverse, multi-storeyed communities dominated by large-stature trees. They are mostly found in Amazonian basin, Mexico, Central America, Caribbean islands, Pacific coast of South America, the Atlantic coast of Brazil and Northern Venezuela. The Indo-Malaysian (sub) tropical formation ranges from India through Polynesia. The wide array of landforms, climates, soils and the degree and types of human activities within the region interact to add further layers of floristic and structural complexity. The monsoons are the dominant climatic factors governing precipitation in the region, and hence determine the occurrence and distribution of evergreen forests (Puri *et al.* 1983).

The subtropical semi-evergreen forests are predominantly evergreen, with some trees of deciduous habit. These forests are found from lowland (1000 m asl) to montane environment and characterized by climbers and evergreen shrub species. Tree ferns are found at lower elevations. Over-story trees that lose their foliage during dry seasons dominate them; the under-storey is often composed of evergreen shrubs and has tree ferns at lower elevation. Ground cover is dense and woody climbers are also present in the forest. Structurally, these forests are similar to the tropical evergreen forests, but are less productive due to periods of low temperatures during the winters (Evans 2001).

In India, subtropical forests were found between 1000 m and 1700 m asl on the higher hills of south India and northeast India and both regions have been subjected to shifting cultivation that has greatly affected the vegetation (Champion and Seth 1968). Their canopy density is much less than the evergreen forests due to presence of few emergent trees above the canopy layer. The tree height in the canopy layer ranges between 20 m and 30m. The forest is characterized by heavy growth of epiphytic mosses, ferns and flowering plants. The species richness of these forests is high due to presence of temperate and tropical species.

The annual rainfall is generally over 200 cm with four to five dry (<70 mm rainfall) months (November to March). The humidity remains fairly high (55%-85%) even during dry period owing to the montane situation. The mean annual temperature ranges from 15 ^{0}C to 23 ^{0}C.

Owing to the diverse ecological conditions such as wide variation in rainfall, temperature, altitude as well as soil conditions, the inaccessible humid areas of the state of Meghalaya support luxuriant growth of tropical and subtropical vegetation, which is rich in angiospermic flora.

This chapter presents data on plant diversity, community structure, tree population structure and regeneration behaviour of dominant tree species in three stands of subtropical semi-evergreen forest found between 1100 m and 1700 m asl in East and West Khasi hills districts of the state.

Plant diversity

Altogether, 179 species belonging to 125 genera and 66 families were recorded from stand SEG-I. The stand SEG-II having 211 species belonging to 144 genera and 72 families, was richer in plant diversity. In stand SEG–I trees were represented by 77 species, 55 genera and 35 families, whereas 102 species, 66 genera and 39 families were present in SEG–II. Tree species contributed 43% to the total species richness, 47.2% to the genera and 53% to the family richness in stand SEG-I, while in stand SEG–II their share was 48.3% in total species richness, 45.8% in genera and 51% in family richness.

The trees were distributed in three distinct strata *i.e.*, canopy (>20 m height), sub-canopy (10-20 m height) and treelet (2-10 m height) layers. The canopy layer had 20 and 13 species, sub-canopy 39 and 32 species, and treelet layer 41 and 30 species in stand SEG–I and II, respectively. Sub-canopy and treelet layers together contributed 78% to 81% of the total tree richness of the forest stands. *Elaeocarpus rugosus, Echinocarpus murex*, *Michelia doltsopa* and *Neolitsea cassia* in SEG–I, and *Beilshmiedia assamica*, *Celtis tetranda*, *Engelhardtia spicata* and *Vitex vestita* in stand SEG–II, were common in the canopy layer of the two stands (Table 6.1a, 6.2a).

There were 23 and 27 shrub species representing 20 and 25 genera and 13 and 20 families in stand SEG-I and II, respectively. *Psychotria erratica*, *Adenia trilobata*, *Eurya japonica*, *Agapetes variegata* were the common species in stand SEG–I, and *Erythroxylum kunthianum*, *Melastoma malabathricum* and *Pittosporum podocarpum* in stand SEG–II (Table 6.1b, 6.2b).

Table 6.1a. Density (number of plants per 1.2ha), basal cover (m^2 ha^{-1}), importance value index and distribution pattern of tree species in stand I of the subtropical semi-evergreen forest (SEG).

Name of species	Family	Density	Basal cover	IVI	*Distribution pattern
Canopy (>20 m height) trees					
Actinodaphne ovabata (Nees.) Bl.	Actinidiaceae	2	0.07	0.6	C
Celtis tetrandra Roxb.	Ulmaceae	11	0.41	4.2	C
Echinocarpus murex Benth.	Elaeocarpaceae	13	0.21	4.6	Ra
Elaeocarpus rugosus Roxb.	Elaeocarpaceae	17	0.5	4.5	C
Litsea laeta Wall. ex Nees.	Lauraceae	4	0.04	1.1	C
Michelia doltsopa DC.	Magnoliaceae	13	0.18	2.4	C
Neolitsea cassia (Linn.) Koster	Lauraceae	11	0.19	2.2	C
Paramichelia baillonii Pierr.	Magnoliaceae	11	0.22	2.3	C
Persea bombycina King. ex Hk.f.	Lauraceae	13	0.19	3.2	C
Persea parviflora Miessn.	Lauraceae	13	0.17	3.5	C
Sapindus rarak DC.	Sapindaceae	14	0.25	4.9	Ra
Schima khasiana Dyer.	Theaceae	14	0.57	4.2	C
Schima wallichii (DC.) Korth.	Theaceae	22	0.85	6.6	C
Sub-canopy (10-20m height) trees					
Aporusa aurea Hk.f.	Euphorbiaceae	14	0.18	3.6	C
Aporusa oblonga Muell.-Arg.	Euphorbiaceae	19	0.85	8.3	Ra
Bridelia pubescens Kurz.	Euphorbiaceae	13	0.32	4	C
Cleidion spiciflorum Burm.	Euphorbiaceae	13	0.36	4.4	C
Cordia fragrantissima Kurz.	Boraginaceae	3	0.06	2.2	Re
Cordia grandis Roxb.	Boraginaceae	12	0.3	2.9	C
Cryptocarya amygdalina Nees.	Lauraceae	10	0.18	3.6	Ra
Daphniphyllum himalayense Benth.	Daphniphyllaceae	13	0.26	2.6	C
Diospyros stricta Roxb.	Ebenaceae	13	0.17	4.2	Ra
Drypetes assamica Hk.f.	Euphorbiaceae	12	0.16	2.3	C
Ficus elastica Roxb.	Moraceae	23	0.96	8.7	Ra
Ficus hispida Linn.	Moraceae	11	0.23	3.3	C
Ficus oligodon Miq.	Moraceae	23	0.91	8.8	Ra
Garcinia cowa Roxb. ex. DC.	Clusiaceae	14	0.37	4	C
Garcinia paniculata (G.Don.) Roxb	Clusiaceae	13	0.09	1.9	C
Glochidion acuminatum Muell.-Arg.	Euphorbiaceae	18	0.45	5.8	Ra
Glochidion assamicum Hk.f.	Euphorbiaceae	3	0.06	0.9	C
Glochidion khasicum Hk.f.	Euphorbiaceae	16	0.2	3.4	C
Helicia nilagirica Bedd.	Proteaceae	20	0.52	4.7	C
Macropanax undulatus (Wall.ex D. Don.) Seem.	Araliaceae	11	0.2	3.2	C
Meliosma wallichii Planch.ex Hk.f.	Sabiaceae	14	0.3	4.7	Ra
Myrica esculenta Buch.-Ham.	Myricaceae	14	0.61	4.1	C
Polyalthia cerasoides Roxb.	Annonaceae	15	0.24	3.5	C
Polyalthia jenkinsii Benth. & Hk.f.	Annonaceae	13	0.11	3.4	C
Premna latifolia Roxb.	Verbenaceae	11	0.22	3.5	C

Quercus serrata Thunb.	Fagaceae	28	0.38	6.2	C
Randia wallichii Hk.f.	Rubiaceae	30	0.48	6.7	C
Rhododendron arboreum Smith.	Ericaceae	21	0.52	6.6	Ra
Rhus acuminata DC.	Anacardiaceae	18	0.61	4.7	C
Rhus javanica Linn.	Anacardiaceae	11	0.17	3.3	C
Sterculia roxburghii Wall.	Sterculiaceae	13	0.25	4.5	Ra
Wendlandia grandis Cowan.	Rubiaceae	2	0.09	0.7	C
Treelet (2-10 m height) layer					
Anacardium occidentale Linn.	Anacardiaceae	14	0.5	4.7	C
Aporusa dioica Roxb.	Euphorbiaceae	16	0.51	4.1	C
Aquilaria khasiana Hall.	Aquifoliaceae	13	0.26	4.8	Ra
Ardisia floribunda Wall.	Myrsinaceae	11	0.19	3.3	C
Camellia caudata Wall.	Theaceae	14	0.24	5	Ra
Camellia cauduca Brandis.	Theaceae	14	0.21	3.1	C
Camellia kissi Wall.	Theaceae	18	0.31	4.4	C
Daphne involucrata Wall.	Thymeliaceae	13	0.12	2.9	C
Eriobotrya angustissima Hk. f.	Rosaceae	13	0.24	3.4	C
Erythroxylum kunthianum Kurz.	Erythroxylaceae	15	0.34	3.8	C
Eurya acuminata DC.	Theaceae	19	0.21	3.6	C
Eurya japonica Thunb.	Theaceae	21	0.24	4.3	C
Gaultheria fragrantissima Wall.	Ericaceae	10	0.43	2.8	C
Ilex odorata D. Don.	Aquifoliaceae	13	0.34	3	C
Leucosceptrum canum Sm.	Laminaceae	15	0.53	6.1	Ra
Ligustrum lucidum Ait.f.	Oleaceae	11	0.41	3	C
Ligustrum robustum (Roxb.) Bl.	Oleaceae	16	0.21	3.3	C
Litsea salicifolia Roxb.ex. Nees.	Lauraceae	12	0.35	3.5	C
Pandanus odoratissimus (Lamk.) Linn.	Pandanaceae	18	0.59	5.6	C
Persea duthiei King ex. Hk.f.	Lauraceae	19	1.35	8.4	C
Psychotria adenophylla Wall.	Rubiaceae	13	0.28	2.7	C
Psychotria symplocifolia Kurz.	Rubiaceae	13	0.35	3.3	C
Quercus glauca Thunb.	Fagaceae	18	0.29	3.9	C
Quercus griffithii Hk.f. & Th.	Fagaceae	14	0.11	3	C
Randia griffithii Hk.f.	Rubiaceae	10	0.25	3.3	C
Randia longiflora Lamk.	Rubiaceae	15	0.4	4.2	C
Symplocos laurina (Reitz.) Wall.	Symplocaceae	12	0.19	2.2	C
Symplocos paniculata Thunb.	Symplocaceae	12	0.2	3.2	C
Viburnum foetidum Wall.	Caprifoliaceae	13	0.28	3.2	C
Zanthoxylum armatum DC.	Rutaceae	10	0.1	1.5	C
Large woody climbers					
Embelia floribunda Wall.	Myrsinaceae	10	0.17	3	C
Sabia lanceolata Colebr.	Sabiaceae	13	0.18	4.3	Ra
		1063	**25.08**	**300**	

*C= contagious, Ra= random, Re= regular distribution pattern.

Table 6.2a. Density (number of plants per 1.2ha), basal cover (m^2 ha^{-1}), importance value index and distribution pattern of tree species in stand II of the subtropical semi-evergreen forest (SEG).

Name of species	Family	Density	Basal cover	IVI	*Distribution pattern
Canopy (>20 m height) trees					
Beilshmiedia assamica Meissn.	Lauraceae	17	1.41	6.89	Ra
Celtis cinnamomea Lindl.ex Planch	Ulmaceae	9	0.44	3.01	C
Celtis tetrandra Roxb.	Ulmaceae	4	0.12	1.33	C
Dysoxylum binectariferum Hk.f.et Bedd.	Meliaceae	18	3.51	11.04	Ra
Echinocarpus dasycarpus Benth.	Elaeocarpaceae	14	0.13	3.7	Ra
Echinocarpus murex Benth.	Elaeocarpaceae	6	0.27	1.53	C
Elaeocarpus floribundus Bl.	Elaeocarpaceae	9	0.39	3.05	C
Elaeocarpus lanceaefolius Roxb.	Elaeocarpaceae	2	0.09	0.53	C
Elaeocarpus rugosus Roxb.	Elaeocarpaceae	8	1.53	4.56	C
Engelhardtia spicata Leschn ex Bl.	Juglandaceae	12	1.21	5.59	Ra
Michelia champaca Linn.	Magnoliaceae	9	0.28	2.84	C
Michelia doltsopa DC.	Magnoliaceae	21	0.43	6.74	Re
Nauclea griffithii Hav.	Rubiaceae	18	0.21	5.44	Re
Persea kingii Hk.f.	Lauraceae	4	0.15	1.09	C
Sapium baccatum Roxb.	Euphorbiaceae	1	0.01	0.26	C
Schima khasiana Dyers	Theaceae	4	0.08	1.09	C
Schima wallichii (DC) Korth.	Theaceae	3	0.03	0.5	C
Syzygium tetragonum Wt.	Myrtaceae	24	2.92	10.83	Ra
Vitex pinnata Linn.	Verbenaceae	11	0.09	3.09	Ra
Vitex vestita Roxb.	Verbenaceae	4	0.04	1.17	C
Sub-canopy (10-20m height) trees					
Actinodaphne pedunculata (Linn.) Miq.	Actinidiaceae	6	0.08	0.99	C
Aporusa aurea Hk.f.	Euphorbiaceae	12	0.21	2.84	C
Ardisia floribunda DC.	Myrsinaceae	2	0.03	0.4	C
Callicarpa arborea Roxb.	Verbenaceae	8	0.03	2.39	Ra
Callicarpa arborea Roxb.	Verbenaceae	8	0.06	1.84	C
Carallia brachiata (Lour.) Merr.	Cannaceae	6	0.18	1.94	C
*Cleidion spiciflorum (*Burm.) Merr.	Euphorbiaceae	3	0.57	1.98	C
Cordia fragrantissima Kurz.	Boraginaceae	12	0.85	4.88	Ra
Cordia grandis Roxb.	Boraginaceae	7	0.08	1.99	Ra
Crptocarya amygdalina Nees	Lauraceae	6	0.63	2.27	C
Cryptocarya andersonii King ex Hk.f.	Lauraceae	5	0.19	1.28	C
Daphniphyllum himalayense (Benth.) Muell.-Arg.	Daphniphyllaceae	23	1.48	8.28	Ra
Drypetes assamica Hk.f.	Euphorbiaceae	9	0.44	3.3	Ra
Eriobotrya dubia Decne.	Rosaceae	19	0.43	5.06	Ra
Ficus elastica Roxb.	Moraceae	11	0.04	2.7	Ra
Ficus hispida Linn.f.	Moraceae	8	0.13	2.56	Ra
Garcinia cowa Roxb.ex DC.	Clusiaceae	3	0.01	0.46	C
Glochidion acuminatum Muell.-Arg.	Euphorbiaceae	6	3.14	7.62	C

Lindera latifolia Hk.f.	Lauraceae	6	0.06	1.4	C
Lindera pulcherrima (Nees.) Benth.	Lauraceae	12	0.13	3.28	Ra
Litsea cubeba Lour.	Lauraceae	5	0.85	2.9	C
Litsea laeta Wall. ex Nees.	Lauraceae	2	0.02	0.53	C
Macropanax undulatus (Wall.ex D.Don.) Seem.	Araliaceae	8	0.26	2.44	C
Meliosma wallichii Planch.ex Hk.f.	Sabiaceae	2	0.03	0.57	C
Michelia oblonga Wall. ex Hk.f.	Magnoliaceae	4	0.03	1.15	C
Michelia punduana Hk.f.	Magnoliaceae	2	0.02	0.38	C
Ostodes paniculata Bl.	Euphorbiaceae	2	0.02	0.38	C
Persea gamblei King.ex Hk.f.	Lauraceae	6	0.17	1.61	C
Persea khasyana Meissn.	Lauraceae	2	0.18	0.84	C
Phoebe lanceolata Nees.	Lauraceae	3	0.03	0.61	C
Picrasma javanica Bl.	Simaroubaceae	4	0.03	1.13	C
Polyalthia longifolia Benth. & Hk.f.	Annonaceae	9	0.07	2.56	Ra
Prunus nepaulensis (Ser.) Steud.	Rosaceae	11	3.38	9.88	Ra
Sapindus rarak DC.	Sapindaceae	6	0.13	1.4	C
Sapium eugeniaefolium Ham.ex Hk.f.	Euphorbiaceae	12	0.3	3.76	Ra
Sterculia hamiltonii (O.) Ktze.	Sterculiaceae	6	0.35	2.28	C
Syzygium formosum Wall.	Myrtaceae	34	3.83	15.33	Re
Trevesia palmata (Roxb.)	Araliaceae	9	0.23	3.33	Re
Vernonia volkameriifolia DC.	Asteraceae	8	0.08	1.94	C

Treelet (2-10 m height) layer

Actinidia collosa Lindl.	Actinidiaceae	13	0.27	2.92	C
Antidesma acidum Retz.	Euphorbiaceae	23	0.62	7.55	Re
Beilshmiedia fagifolia Nees	Lauraceae	9	2.58	7.62	Ra
Beilshmiedia roxburghiana Nees	Lauraceae	3	0.6	1.91	C
*Brassiopsis glomerulata (*Bl.) Regel.	Araliaceae	12	1.06	5.29	Ra
Cinnamomum bejolghota Buch.-Ham.	Lauraceae	6	0.29	1.73	C
Cinnamomum pauciflorum Nees.	Lauraceae	3	0.3	1.05	C
Citrus medica Linn.	Rutaceae	15	2.71	9.16	Ra
Citrus sp.	Rutaceae	17	0.08	4.06	Ra
Coffea khasiana Hk.f.	Rubiaceae	3	0.07	0.58	C
Ficus oligodon Miq.	Moraceae	3	0.03	0.49	C
Glochidion khasicum Hk.f.	Euphorbiaceae	4	0.03	1.29	C
Grewia microcos Linn.	Tiliaceae	19	0.23	4.65	Ra
Ligustrum robustum Roxb. Bl.	Oleaceae	9	0.05	2.37	C
Litsea salicifolia (Roxb.ex Nees.) Hk.f.	Lauraceae	4	0.18	1.31	C
Micromelum integrimum (Roxb.) Wt. & Arn.	Rutaceae	3	0.02	0.87	C
Myrica esculenta Buch.-Ham.ex D. Don.	Myricaceae	4	0.08	1.24	C
Myrsine capitellata Wall.	Myrsinaceae	8	0.09	1.37	C
Olea dentata Wall.ex DC.	Oleaceae	6	0.04	1.66	C
Olea dioica Roxb.	Oleaceae	7	0.08	1.98	Ra
Persea bombycina King.ex Hk.f.	Lauraceae	16	0.29	4.69	Ra
Persea duthiei King.ex Hk.f.	Lauraceae	11	0.13	3.31	Ra
Pittospermum nepalense Gagnep.	Pittosporaceae	12	0.24	3.06	C

Psychotria symplocifolia Kurz.	Rubiaceae	2	0.02	0.53	C
Pyrus pashia D.Don.	Rosaceae	8	5.08	12.34	Ra
Quercus glauca Thunb.	Fagaceae	3	0.03	0.74	C
Quercus griffithii Hk.f. & Th.ex DC.	Fagaceae	7	0.03	1.74	C
Quercus serrata Hk.f. & Th.	Fagaceae	6	0.13	1.69	C
Randia griffithii Lamk.	Rubiaceae	4	0.08	1.25	C
Rhus acuminata DC.	Anacardiaceae	8	0.09	2.11	C
Rhus javanica Linn.	Anacardiaceae	7	0.03	1.29	C
Salix tetrasperma Roxb.	Salicaceae	43	0.93	10.43	Ra
Sarcococca saligna (D. Don) Muell.-Arg.	Buxaceae	2	0.02	0.39	C
Schefflera elata Linn.	Araliaceae	3	0.06	0.96	C
Schefflera glomerata Linn.	Araliaceae	22	0.32	6.02	Re
Schefflera hypoleuca Kurz.	Araliaceae	2	0.05	0.44	C
Symplocos cochinchinensis Lour.	Symplocaceae	1	0.03	0.29	C
Symplocos lucida Thunb.	Symplocaceae	3	0.03	0.51	C
Symplocos paniculata Thunb.	Symplocaceae	1	0.03	0.29	C
Symplocos racemosa Roxb.	Symplocaceae	1	0.05	0.35	C
Vatica lanceaefoli Bl.	Sapindaceae	5	0.03	1.23	C
Large woody climbers					
Fissistigma wallichii Hk.f. & Th.	Annonaceae	2	0.01	0.51	C
Combretum roxburghii Spreng.	Combretaceae	4	0.43	1.96	C
		838	**49.52**	**300**	

*C= contagious, Ra= random, Re= regular distribution pattern.

Table 6.1b. Frequency (%), density (ha^{-1}) and importance value index of shrub species in stand I of the subtropical semi-evergreen forest.

Name of species	Family	Density	Frequency	IVI
Psychotria erratica Hk.f.	Rubiaceae	188	83	23.5
Symplocos paniculata (Thunb.) Miq.	Symplocaceae	152	97	23.2
Adenia trilobata Roxb.	Rubiaceae	156	67	19.2
Rhus javanica Linn.	Anacardiaceae	124	37	12.9
Achronychia pendunculata Miq.	Rutaceae	68	43	10.4
Eurya japonica Thunb.	Theaceae	80	17	10.2
Actinidia callosa Lindl.	Actinidiaceae	64	40	9.7
Gardenia companulata Roxb.	Rubiaceae	84	30	9.5
Baliospermum calycina Muell.-Arg.	Euphorbiaceae	100	13	9.5
Agapetes variegata Roxb.	Vaccinaceae	84	13	8.5
Litsea salicifolia Roxb. ex Nees.	Lauraceae	52	30	7.5
Ardisia odontophylla DC.	Myrsinaceae	60	17	7.5
Glycosmis arborea (Roxb.) DC.	Rutaceae	48	17	6.8
Ardisia griffithii Cl.	Myrsinaceae	52	13	6.6
Ardisia floribunda Wall.	Myrsinaceae	48	13	6.3
Phyllanthus deblis Willd.	Euphorbiaceae	64	17	6.3
Mussaenda roxburghii Hk.f.	Rubiaceae	52	20	6.1
Maesa indica (Roxb.) Wall.	Myrsinaceae	48	20	5.8
Daphne papyracea Wall.	Thymeliaceae	28	20	4.6
Erythroxylum kunthianum Wall.ex Kurz.	Erythroxylaceae	20	7	2.2
Ixora undulata Roxb.	Rubiaceae	16	3	1.5
Pittospermum podocarpum Gagnep.	Pittosporaceae	12	3	1.2
Ixora roxburghii Balakr.	Rubiaceae	8	3	1.0
		1608		**200**

Table 6.2b. Frequency (%), density (ha^{-1}) and importance value index of shrub species in stand II of the subtropical semi-evergreen forest.

Name of species	Family	Density	Frequency	IVI
Ardisia griffithii Cl.	Myrsinaceae	216	27	17.1
Clerodendrum infortunatum auct.non Linn.	Verbenaceae	159	23	14.2
Erythroxylum kunthianum Wall.ex Kurz.	Erythroxylaceae	174	83	14.2
Eupatorium odoratum Linn.	Asteraceae	189	23	14.2
Leptodermis griffithii Hk.f.	Rubiaceae	126	12	12.0
Skimmia laureola (DC.) Sieb & Zucc ex Walp.	Rutaceae	96	17	11.1
Eurya japonica Thunb.	Theaceae	111	19	10.3
Randia longiflora Lamk.	Rubiaceae	105	23	10.3
Fagraea ceilanica Thunb.	Loganiaceae	93	3	8.5
Viburnum foetidum Wall.	Caprifoliaceae	72	11	8.0
Litsea salicifolia (Roxb.ex Nees) Hk.f.	Lauraceae	78	23	7.8
Daphne shillong Banerji.	Thymeliaceae	69	9	7.4
Sarcococca saligna D. Don.	Euphorbiaceae	78	23	7.0
Melastoma malabathricum Linn.	Melastomataceae	75	17	6.9
Ardisia floribunda DC.	Myrsinaceae	54	50	6.2
Pittosporum podocarpum Gagnep.	Pittosporaceae	51	43	5.5
Actinidia callosa Lindl.	Actinidiaceae	51	10	5.3
Symplocos paniculata Thunb.	Symplocaceae	51	10	5.3
Ficus hispida Linn. f.	Moraceae	39	37	4.5
Mycetia longifolia (Wall.) O. Ktze.	Rubiaceae	45	30	4.3
Croton caudatus Geisel.	Euphorbiaceae	36	19	3.6
Phyllanthus raticulatus Poir.	Euphorbiaceae	33	19	3.5
Psychotria symplocifolia Kurz.	Rubiaceae	39	17	3.5
Boehmeria platyphylla D.Don.	Urticaceae	36	17	3.4
Acanthopanax aculeatum Seem.	Araliaceae	39	17	3.0
Neillia thyrsiflora D.Don.	Rosaceae	21	17	2.2
Melastoma nepalensis Lodd.	Melastomataceae	9	7	0.9
		2145		**200**

The herbs were represented by 47 species, 40 genera and 25 families in SEG–I, and by 70 species, 49 genera and 29 families in SEG-II. Apart from the herbaceous flowering plants, the ground layer also had tree seedlings and ferns. *Aphania adnata*, *Cyanotis barbata*, *Paspalum ternatum*, *Begonia rubro-venia*, *Cymbopogon khasianus*, *Digitaria corymbosa*, *Ainsliaea latifolia*, *Pennisetum compressum*, *Echinochloa frumentacea*, *Lindernia hirsuta* and *Ammomum subulatum* were the common herbaceous species in the two stands (Table 6.1c, 6.2c).

Euphorbiaceae with 9 species was the dominant family in stand SEG-I followed by Theaceae and Lauraceae (7 species each), and Rubiaceae (6 species). These families together contributed about 34% of the species richness (26 species), 34% (360 stem ha^{-1}) of the stand density, 32% (8.07 m^2 ha^{-1}) of the basal cover, and 39% of the total family importance in the stand. Seventeen families (48%) were represented by only one species, but they contributed about 21% (219 stem ha^{-1}) to the total stand density and 22% (5.37 m^2 ha^{-1}) to the total basal cover (Table 6.3).

Among the tree species, Lauraceae (represented by 17 species) was the dominant in SEG-I, followed by Euphorbiaceae (9 species), Araliaceae (6 species) and Elaeocarpaceae (5 species). These families together contributed about 51% (431 stem ha^{-1}) to the stand density and 59.8% (32.1 m^2 ha^{-1}) to the basal cover of the stand. Eighteen (46.2%) families were represented by a single species. Their contribution was 21% (179 stem ha^{-1}) to the total stand density and 11% (5.96 m^2 ha^{-1}) to the basal cover of the stand (Table 6.4).

Table 6.1c. Frequency (%), density (per 100 m^2) and importance value index of herbaceous species in stand I of the subtropical semi-evergreen forest.

Name of species	Family	Density	Frequency	IVI
Anotis oxyphylla (D.Don) Hk.f.	Rubiaceae	193	98	13.8
Hemiphragma hetrophyllum Wall.	Scrophulariaceae	178	97	13.1
Davaellia sp.	Davaelliaceae	197	77	12.6
Crysopogon aciculatus Reitz.	Poaceae	119	82	9.9
Aspleinium sp.	Aspleniaceae	99	72	8.4
Gentiana quadriferia Bl.	Gentianaceae	103	19	8.4
Fagraea ceilanica Thunb.	Rosaceae	101	48	8.3
Aphania adnata Wall.ex DC.	Zingiberaceae	92	45	7.7
Ainsliaea latifolia (D.Don)Sch	Asteraceae	82	12	7.1
Commelina sikkimensis Clarke.	Commelianiaceae	68	13	6.6
Andropogon ascinodis Clarke	Andropoganeae	79	12	6.4
Glechenia sp.	Glecheniaceae	76	11	6.2
Digitaria corymbosa Roxb.	Poaceae	71	11	6
Piper griffithii C. DC.	Piperaceae	65	13	5.9
Piper thomsonii Hk.f.	Piperaceae	52	39	4.5
Eriosema chinense (non Vogel) Baker	Fabaceae	43	41	4.3
Hedychium coronarium Koen.	Zingiberaceae	60	31	4.3
Cyperus esculentus Linn.	Cyperaceae	54	32	4.1
Echinochloa frumentacea Link,	Poaceae	43	38	4.1
Cymbopogon khasianus Duthie	Poaceae	47	34	4
Panicum incomtom Train.	Poaceae	53	16	3.7
Annotis calycina Hk.f	Asteraceae	43	29	3.6
Disporum calcaratum D.Don.	Liliaceae	53	24	3.6
Gnaphalium afine D. Don.	Asteraceae	43	28	3.5
Elatostemma rupestre (D.Don) Wedd.	Asteraceae	37	16	3.1
Panicum humidorum Hk.f.	Poaceae	39	11	2.9
Cyanotis barbata D. Don	Commelianiaceae	33	10	2.6
Cyathula tomentosa Miq.	Amaranthaceae	32	21	2.6
Elsholtzia blanda Benth.	Lamiaceae	28	24	2.6
Paspalum congigatum Berz.	Poaceae	38	18	2.6
Elatostemma sessile Forst.	Urticaceae	27	23	2.5
Eragrostis nigra Nees.ex Steud.	Eragrosteae	33	13	2.5
Paspalum ternatum Hk.f.	Poaceae	33	17	2.2
Eleusine corocana (Linn.) Gaertn	Poaceae	33	13	2.1
Plantago major Linn.	Plantaginaceae	27	16	2.1
Begonia roxburghii A.DC. Prodr.	Begoniaceae	24	17	2
Gardenia companulata Roxb.	Rubiaceae	21	16	1.8
Cyanotis cristata (Linn) D.Don.	Commelinaceae	14	9	1.1
Anaphalis timmua D. Don.	Asteraceae	12	8	0.9
Ophiopogon parviflorus Hk.f.	Liliaceae	13	6	0.9
Polygonum nepalense Meissn.	Polygonaceae	12	7	0.9
Begonia rubro-venia Hk.f.	Begoniaceae	11	7	0.8
Drymaria cordata (Linn) Roem. & Schutt.	Polypodiaceae	11	7	0.8

Hedera nepalensis K. Koch.	Araliaceae	9	7	0.8
Molineria capitulata Lour.	Hypoxidaceae	9	7	0.8
Anotis waghitiana Hk.f.	Rubiaceae	3	2	0.2
Lindenbergia muraria Roxb.	Scrophulariaceae	3	2	0.2
		3013		**200**

Table 6.2c. Frequency (%), density (per 100 m^2) and importance value index of herbaceous species in stand II of the subtropical semi-evergreen forest.

Name of species	Family	Density	Frequency	IVI
Andropogon ascinodis Clarke	Andropoganeae	193	93	11.4
Raphidophora decursiva (Roxb.)	Araceae	136	81	8.8
Ophiopogon parviflorus Hk.f.	Liliaceae	135	77	8.6
Rubus rugosus Smith.	Rosaceae	128	60	7.4
Cymbopogon khasianus Duthiei.	Andropoganeae	93	69	6.8
Begonia roxburghii A.DC. Prodr.	Begoniaceae	101	57	6.4
Aeschyranthus paracitica Bl.	Gesneriaceae	110	34	5.5
Ainsliaea latifolia (D.Don) Sch.	Asteraceae	71	60	5.5
Aeschyranthus sikkimensis (Cl.) Stapf.	Gesneriaceae	79	52	5.4
Cyanotis cristata (Linn) D.Don.	Commelinaceae	72	56	5.3
Dendrobium formosum Roxb.	Orchidaceae	68	52	5
Ammomum subulatum Roxb.	Zinziberaceae	77	43	4.9
Buettneri pilosa Roxb.	Sterculiaceae	73	43	4.7
Dendrobium pauciflorum King. & Pantl.	Orchidaceae	46	60	4.7
Piper griffithii C.DC.	Piperaceae	72	39	4.6
Paspalum orbiculare Forst.	Poaceae	56	39	4.2
Hedera nepalensis K. Koch.	Araliaceae	52	39	4.1
Lindenbergia muraria Roxb.	Scrophulariaceae	53	39	4.1
Eragrostis nigra Nees.ex Steud.	Eragrosteae	60	35	3.9
Lindernia hirsuta Benth.	Scrophulariaceae	56	38	3.8
Panicum incomtom Train.	Poaceae	52	39	3.8
Cyathula tomentosa Miq.	Amaranthaceae	54	34	3.6
Begonia rubro-venia Hk.f.	Begoniaceae	52	29	3.3
Anaphalis timmua D.Don.	Asteraceae	43	31	3.1
Polygonum chinense Linn.	Asclepiadaceae	43	32	3.1
Poulzolzia hirta Hassk.	Urticaceae	43	28	2.9
Aeschyranthus suberba Cl.	Gesneriaceae	38	29	2.8
Panicum humidorum Hk.f.	Poaceae	35	29	2.7
Paspalum congigatum Berz.	Poaceae	43	14	2.7
Elatostemma sessile Forst.	Urticaceae	43	13	2.6
Piper longum Linn.	Piperaceae	34	18	2.6
Pennicetum compressum R.Br.	Paniaceae	30	18	2.5
Gentiana quadriferia Bl.	Gentianaceae	44	18	2.4
Echinochloa frumentacea Link.	Poaceae	38	19	2.3
Hedychium coronarium Koen.	Zingiberaceae	31	14	2.3
Raphidophora longifolia Schott.	Araceae	34	12	2.3
Paspalum ternatum Hk.f.	Poaceae	24	17	2.2

Piper thumsonii Hk.f.	Piperaceae	27	19	2.2
Molineria capitulata Lour.	Hypoxidaceae	31	18	2
Aphania adnata Wall.ex DC.	Zingiberaceae	28	18	1.9
Piper betle Linn.	Piperaceae	27	19	1.9
Scutellaria roxburghiana Wall.	Labiateae	33	15	1.9
Rhynchotechum ellipticum Dietr.	Gesneriacaeae	31	14	1.8
Anotis waghtiana Hk.f.	Rubiaceae	32	13	1.7
Disporum calcaratum D.Don.	Liliaceae	27	16	1.7
Achyranthes aspera Linn.	Amaranthaceae	30	12	1.6
Coelogyne punctulata Lindl.	Orchidaceae	18	16	1.4
Mikania micrantha Kunth	Asteraceae	21	14	1.4
Plantago erosa Wall.ex D. Don.	Plantaginaceae	20	14	1.4
Tacca laevis Roxb.	Taccaceae	18	14	1.4
Periploca calophylla (Wt) Fale.	Asclepiadaceae	18	14	1.3
Stephania hemandifolia (Wild.) Walp.	Menispermaceae	19	13	1.3
Viola excelsa Bl.	Violaceae	18	14	1.3
Rubus nivens Thunb.	Rosaceae	18	11	1.2
Viola sp.	Violaceae	16	11	1.1
Anotis oxyphylla (D.Don) Hk.f.	Rubiaceae	14	8	0.9
Torenia vagans Roxb.	Scrophulariaceae	13	9	0.9
Pholidota articulata Lindl.	Orchidaceae	11	8	0.8
Senecio cappa Buch.-Ham.ex D. Don.	Asteraceae	11	8	0.8
Potentilla kleiniana W. & A.	Rosaceae	14	4	0.7
Rubus ellipticus Smith.	Rosaceae	11	7	0.7
Siegesbeckia orientalis Linn.	Asteraceae	10	8	0.7
Smilax ferox Kunth.	Smilacaceae	11	6	0.7
Stephania japonica (Thunb.) Miers.	Menispermaceae	9	8	0.7
Bulbophyllum griffithii (Lindl.) Reichb.f.	Orchidaceae	10	4	0.6
Senecio scandens Buch.-Ham.ex D. Don.	Asteraceae	6	4	0.4
Smilax perifoliata Lour.	Smilacaceae	6	3	0.4
Stephania alegans Hk.f.	Menispermaceae	4	3	0.3
Aeschyranthus hookeri Clarke	Gesneriacaeae	4	2	0.2
Perycampylus glaucus (Lamk.) Merr.	Menispermaceae	4	2	0.2
		2976		**200**

Table 6.3. Importance value of different families in stand I of the subtropical semi-evergreen forest.

Family rank	Family	Species	Individuals (ha^{-1})	Basal cover (m^2 ha^{-1})	*FIV
1	Euphorbiaceae	9	124	3.1	35.7
2	Theaceae	7	117	2.7	30.7
3	Lauraceae	7	82	2.5	26.7
4	Rubiaceae	6	81	1.9	22.8
5	Moraceae	3	57	2.1	17.6
6	Anacardiaceae	3	43	1.3	13.1
7	Fagaceae	3	60	0.8	12.7
8	Ericaceae	2	31	1.0	9.3
9	Elaeocarpaceae	2	30	0.7	8.3
10	Oleaceae	2	27	0.6	7.6
11	Aquifoliaceae	2	26	0.6	7.4
12	Sabiaceae	2	27	0.5	7.1
13	Clusiaceae	2	27	0.5	7.0
14	Annonaceae	2	28	0.4	6.6
15	Magnoliaceae	2	24	0.4	6.5
16	Symplocaceae	2	24	0.4	6.4
17	Myrsinaceae	2	21	0.4	6.0
18	Boraginaceae	2	15	0.4	5.4
19	Pandanaceae	1	18	0.6	5.4
20	Proteaceae	1	20	0.5	5.3
21	Myricaceae	1	14	0.6	5.1
22	Lamiaceae	1	15	0.5	4.8
23	Erythroxylaceae	1	15	0.3	4.1
24	Ulmaceae	1	11	0.4	4.0
25	Caprifoliaceae	1	13	0.3	3.6
26	Sapindaceae	1	14	0.3	3.6
27	Daphniphyllaceae	1	13	0.3	3.6
28	Sterculiaceae	1	13	0.3	3.5
29	Rosaceae	1	13	0.2	3.5
30	Verbenaceae	1	11	0.2	3.2
31	Ebenaceae	1	13	0.2	3.2
32	Araliaceae	1	11	0.2	3.1
33	Thymeliaceae	1	13	0.1	3.0
34	Rutaceae	1	10	0.1	2.6
35	Actinidiaceae	1	2	0.1	1.8
		77	**1063**	**25.1**	**300**

*Family Importance Value

Table 6.4. Importance value of different families in stand II of the subtropical semi-evergreen forest.

Family rank	Family	Species	Individuals (ha^{-1})	Basal cover ($m^2 ha^{-1}$)	*FIV
1	*Lauraceae*	17	176	17.1	68.7
2	Euphorbiaceae	9	123	7.2	35.5
3	Araliaceae	6	87	1.5	17.6
4	Elaeocarpaceae	5	45	3.8	17.1
5	Annonaceae	3	18	5.2	15.1
6	Fagaceae	3	67	0.5	10.5
7	Daphniphyllaceae	2	29	2.2	9.3
8	Rubiaceae	4	43	0.4	8.9
9	Symplocaceae	4	38	0.3	8.3
10	Theaceae	2	22	1.2	6.6
11	Magnoliaceae	4	16	0.4	6.3
12	Rosaceae	3	20	0.6	6.2
13	Verbenaceae	3	21	0.5	6.2
14	Oleaceae	3	29	0.2	6.1
15	Sterculiaceae	1	18	1.7	6.1
16	Myricaceae	3	17	0.7	6
17	Anacardiaceae	3	19	0.2	5.1
18	Boraginaceae	2	19	0.5	5
19	Ulmaceae	2	12	0.7	4.6
20	Simaroubaceae	1	28	0.2	4.3
21	Myrtaceae	2	16	0.2	4
22	Buxaceae	2	2	0.8	3.8
23	Clusiaceae	1	7	1.0	3.7
24	Meliaceae	1	23	0.2	3.7
25	Sapindaceae	2	9	0.2	3.1
26	Asteraceae	1	11	0.5	3
27	Juglandaceae	1	17	0.1	2.8
28	Myrsinaceae	1	11	0.3	2.6
29	Sabiaceae	1	11	0.2	2.5
30	Rutaceae	1	7	0.2	2.1
31	Zingiberaceae	1	10	0.1	2.1
32	Combretaceae	1	8	0.1	1.9
33	Moraceae	1	7	0.1	1.8
34	Pittosporaceae	1	5	0.2	1.8
35	Saliaceae	1	4	0.2	1.7
36	Cannaceae	1	5	0.1	1.6
37	Actinidiaceae	1	2	0.1	1.4
38	Tiliaceae	1	2	0.1	1.4
39	Leguminosae	1	3	0.1	1.3
		102	**1007**	**49.5**	**300**

*Family Importance Value

Dominance-distribution of family importance value showed that 6 families (Euphorbiaceae, Theaceae, Lauraceae, Araliaceae, Elaeocarpaceae and Rubiaceae) were dominant in the two forest stands, while the rest of them had low family importance value (Fig. 6.1).

Community structure

Life-form spectrum

Life form spectra of the two stands presented in Figure 6.2, showed preponderance of phanerophytes (53% to 55%) in both the stands. They were followed by chamaephytes (18%) and therophytes (14%) in stand SEG–I and therophytes (20%) and chamaephytes (16%) in stand SEG-II.

Vertical structure

Profile diagrams drawn along 40 m long and 5 m wide transects revealed distinctly stratified community with trees distributed in three layers. In stand SEG-I, the canopy layer was composed mainly of *Nauclea griffithii*, *Celtis cinnamomea*, *Elaeocarpus rugosus*, *Engelhardtia spicata*, *Dysoxylum binectariferum* and *Cryptocarya andersonii*. The sub-canopy layer of the forest was formed by *Callicarpa arborea*, *Cleidion spiciflorum*, *Lindera latifolia*, *Cordia grandis*, *Elaeocarpus lancaefolius*, and *Garcinia cowa*. *Antidesma acidum*, *Cinnamomum pauciflorum*, *Ficus hispida*, *Schefflera elata*, *Glochidion khasicum*, and *Olea dioca* were the common species in the treelet layer (Fig. 6.3).

In stand SEG–II, *Echinocarpus murex*, *Elaeocarpus rugosus*, *Paramichelia baillonii* and *Schima wallichii* were the common tree species of the

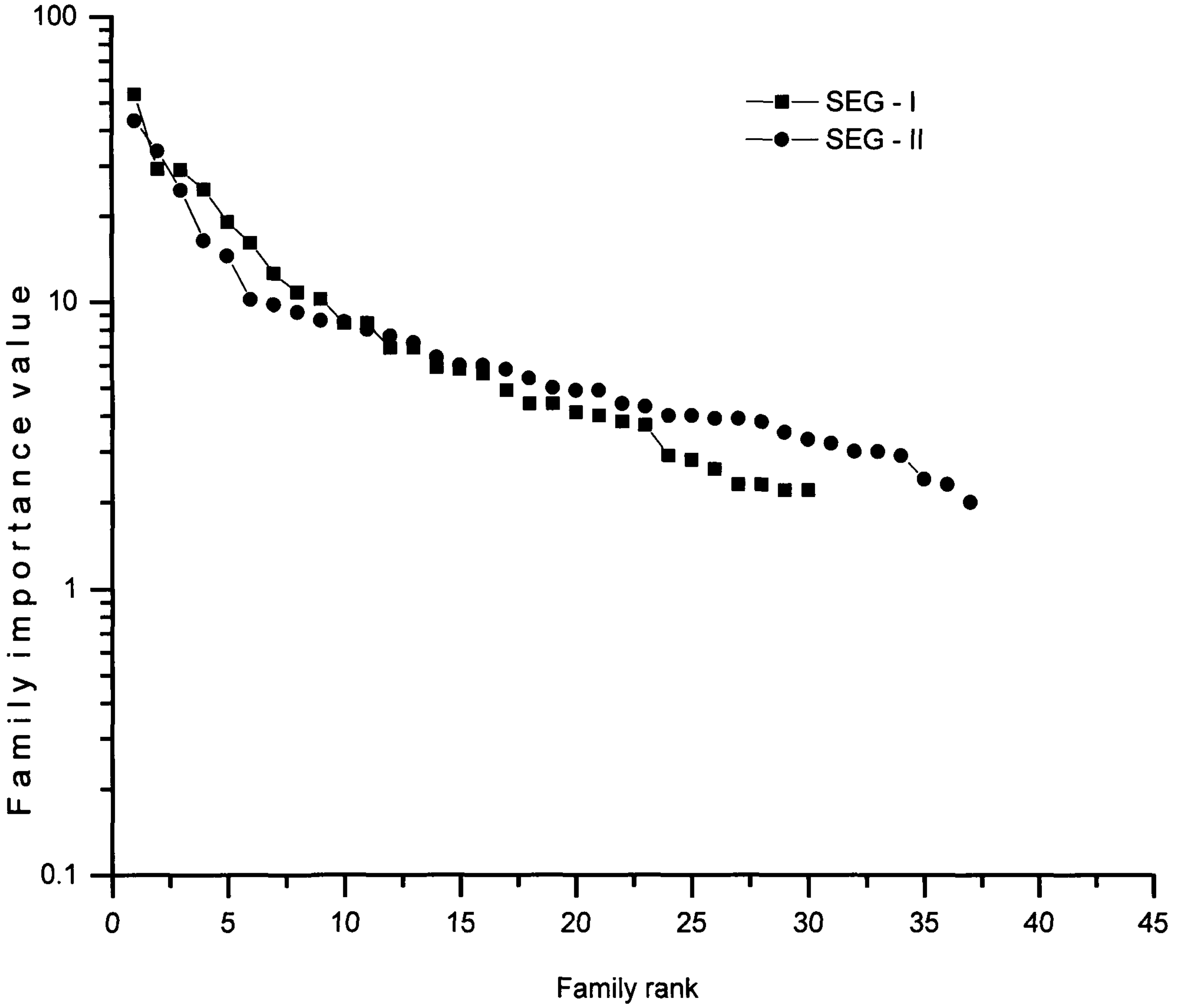


Fig. 6.1. Dominance-distribution in different famlies of the tree species (family names are given in Table 6.3, 6.4) in two stands of the semi-evergreen forest.

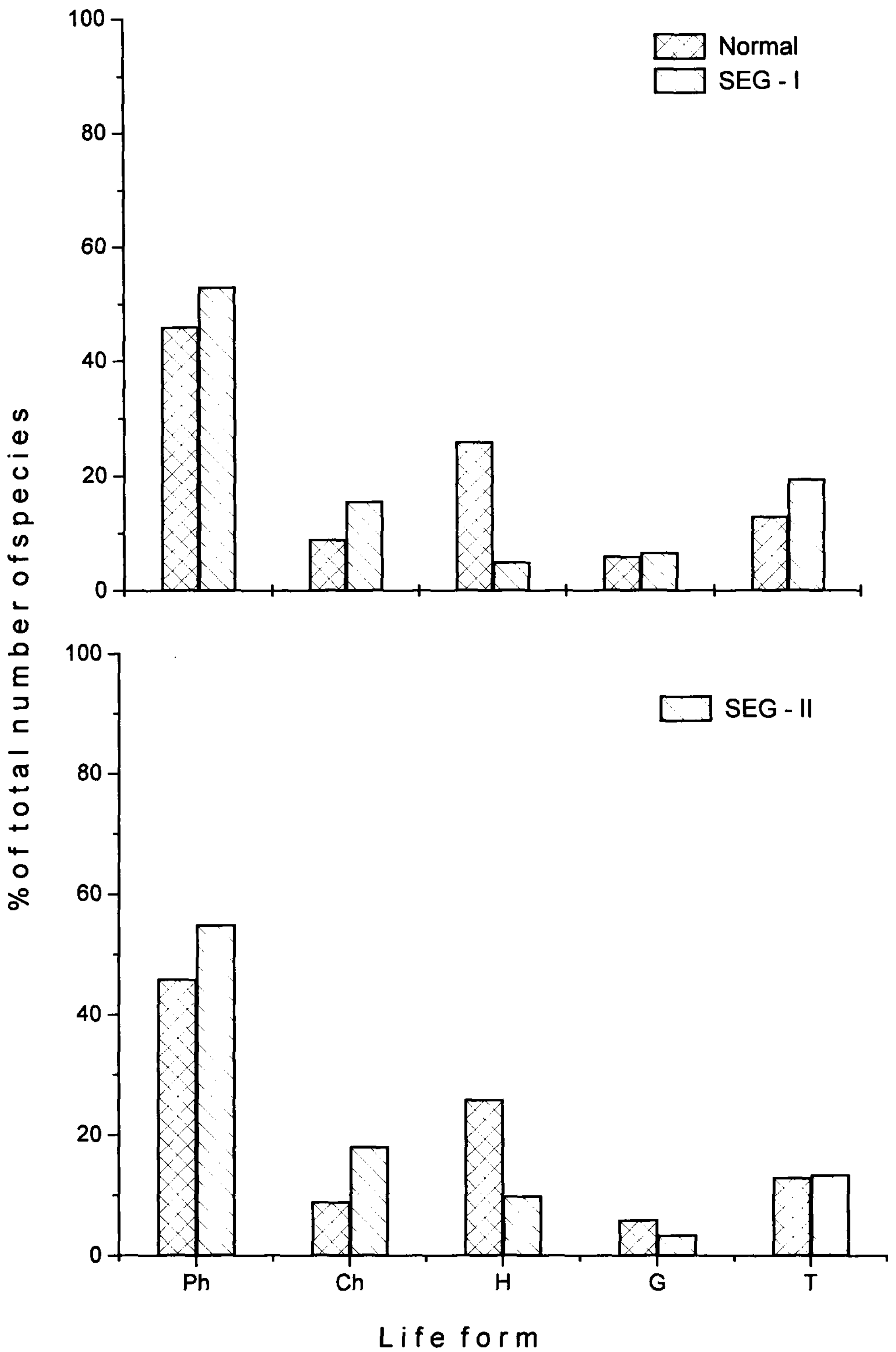


Fig. 6.2. Life form spectra of two (SEG-I, SEG-II) stands of the subtropical semi-evergreen forest (Ph-Phanerophytes, Ch-Chamaephytes, H-Hemicryptophytes, G-Geophytes, T-Theropyhtes).

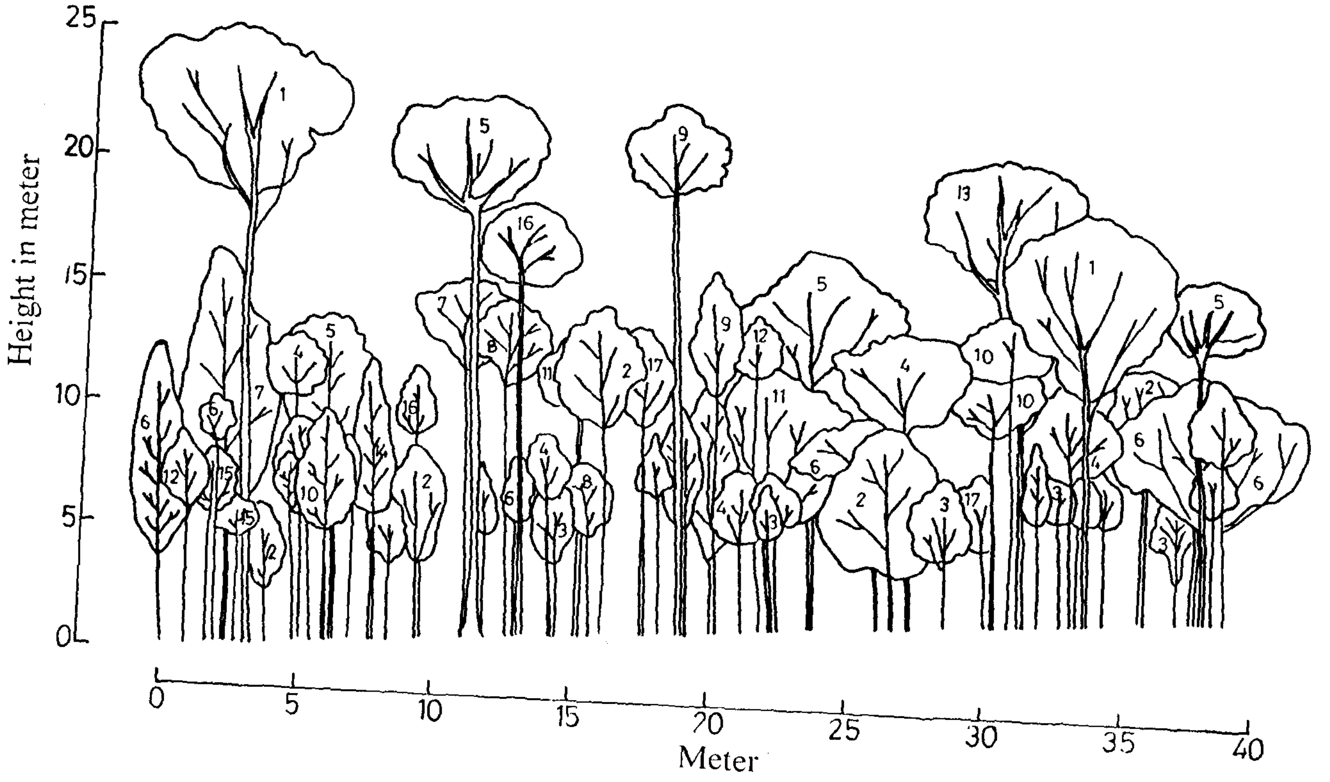


Fig. 6.3. Profile diagram of a subtropical semi-evergreen (SEG-II) forest. The diagram represents a strip of forest (25 m long and 5 m wide). 1. *Beilschmeidia assamica*, 2. *Callicarpa arborea*, 3. *Cinnamomum pauciflorum*, 4. *Cordia fragrantissima*, 5. *Elaeocarpus rugosus*, 6. *Ficus hispida*, 7. *Schefflera glomerata*, 8. *Aporusa aurea*, 9. *Celtis tetranda*, 10. *Lindera latifolia*, 11. *Michelia champaca*, 12. *Quercus glauca*, 13. *Schima wallichii*, 14. *Picrasma javanica*, 15. *Persea duthiei*, 16. *Sapindus rarak*, 17. *Symplocos racemosa*.

canopy layer. The sub-canopy was contributed mainly by *Aporusa aurea*, *Diospyros stricta*, *Ficus oligodon*, *Glochidion assamicum*, *Meliosma wallichii*, and *Rhus javanica*, while *Psychotria adenophylla*, *Symplocos paniculata*, *Eurya japonica*, *Viburnum foetidum*, *Camellia kissi*, *Ligustrum lucidum* and *Daphne involucrata* were common in the treelet layer (Fig. 6.4).

Distribution pattern of species

Majority (67% to 79%) of the tree species in the two stands exhibited clumped or contagious distribution; 20% to 28% species were randomly distributed and 1% to 6% species showed regular distribution (Table 6.5). Similarly, most shrubs (41% to 84%) and herbs (66% to 80%) also showed clumped distribution in both the stands.

Table 6.5. Distribution pattern and Whitford index of trees (T), shrubs (S) and herbaceous (H) species in the two subtropical semi-evergreen forest stands. Values in parentheses are the percentages of the total number of species.

Distribution pattern	**SEG-I**			**SEG-II**		
	T	**S**	**H**	**T**	**S**	**H**
Regular	6 (5.9)	15 (25.9)	6 (5.8)	1 (1.3)	1 (1.3)	14 (15.7)
Random	28 (27.5)	19 (32.7)	24 (23.3)	15 (19.5)	11 (14.7)	16 (18)
Contagious	68 (66.7)	24 (41.4)	73 (70.9)	61 (79.2)	63 (84)	59 (66.3)
	102 (100)	**58 (100)**	**103 (100)**	**77 (100)**	**75 (100)**	**89 (100)**

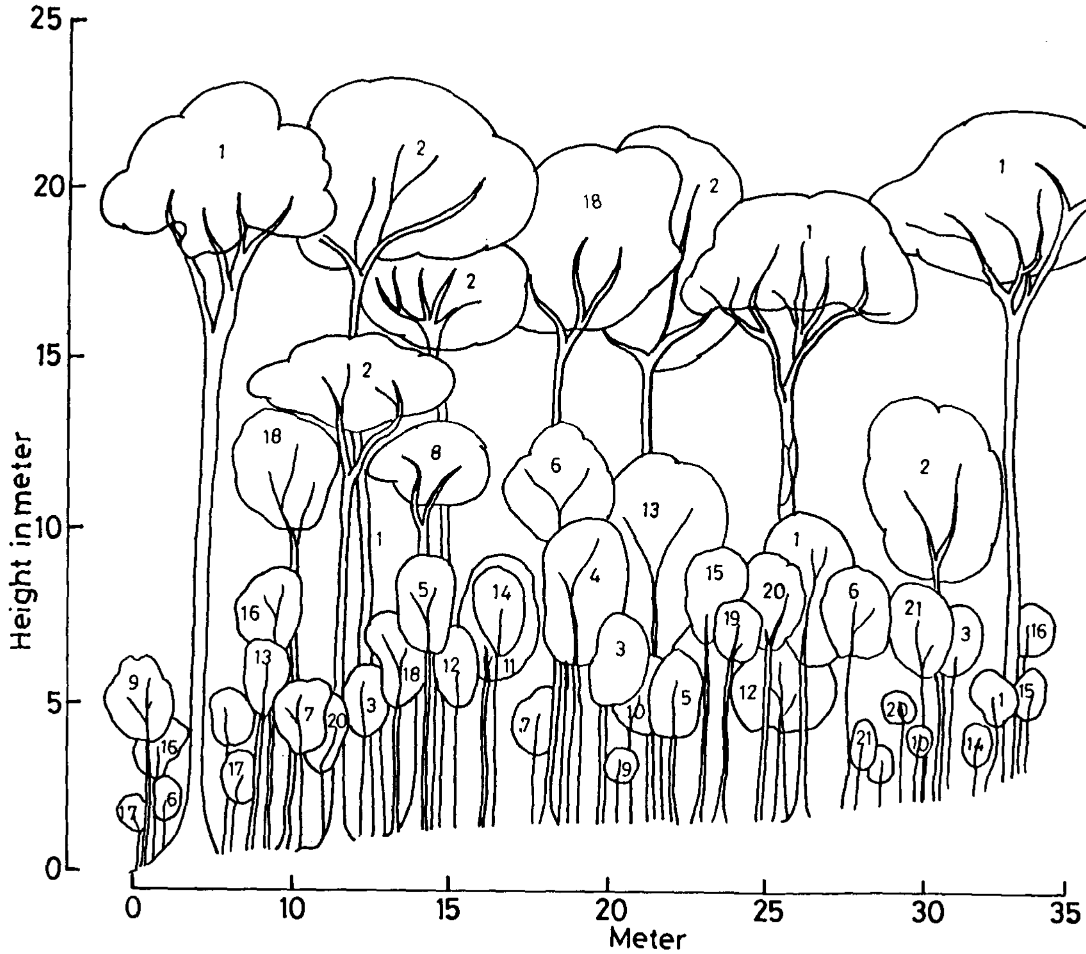


Fig. 6.4. Profile diagram of a subtropical semi-evergreen (SEG-1) forest. The diagram represents a strip of forest (25 m long and 5 m wide). 1. *Schima wallichii*, 2. *Paramichelia ballionii*, 3. *Eurya japonica*, 4. *Garcinia cowa*, 5. *Helicia nilagirica*, 6. *Rhus acuminata*, 7. *Camellia kissii*, 8. *Sapindus rarak*, 9. *Ilex odorata*, 10. *Rhododendron arboreum*, 11. *Glochidion assamica*, 12. *Ficus elastica*, 13. *Echinocarpus murex*, 14. *Meliosma wallichii*, 15. *Bridelia retusa*, 16. *Actinodaphne obovata*, 17. *Ficus hispida*, 18. *Cryptocarya amygdalina*, 19. *Polyalthia jenkinsii*, 20. *Cordia fragrantissima*, 21. *Anacardium occidentale*.

Frequency

In both the stands majority (60% to 62%) of tree species showed low frequency (<20%). *Ficus racemosa*, *Aporusa oblonga*, *Glochidion assamica* and *Camellia caudata* in stand SEG–I, and *Syzygium formosum*, *Salix tetrasperma*, *Daphniphyllym himalyense* and *Antidesma acidum* in the SEG–II were among the most frequently found tree species (Fig. 6.5).

Among the shrub species, *Symplocos paniculata*, *Psychotria erratica*, *Adenia trilobata*, *Achronychia pedunculata* and *Actinidia callosa* in SEG-I, and *Erythroxylum kunthianum*, *Ardisia floribunda*, *Pittosporum podocarpum* and *Ardisia griffithii* in SEG–II were most frequent (Fig. 6.5). About 59% to 65% shrub species were distributed in Raunkiaer's frequency class A.

About 60-66% of the herbaceous species had <20% frequency in the two stands (Fig. 6.5). *Anotis oxyphylla*, *Hemiphragma hetrophyllum*, *Davaellia* sp., *Crysopogon aciculatus* and *Aspleinium* sp. in stand SEG–I, and *Andropogon ascinodis*, *Raphidophora decursiva*, *Ophiopogon parviflorus*, *Rubus rugosus*, *Cymbopogon khasianus* and *Ainsliaea latifolia* in SEG–II had higher frequency values.

Stand density and basal cover

A total of 1063 ±32 and 838 ±14 individuals ha^{-1} of tree species were recorded from SEG-I and II, respectively. Middle girth class (35-75 cm cbh) trees contributed 54% to 90% of the stand density in both the stands. The lower girth class (15-35 cm cbh) accounted for 8% and 13% and higher girth class

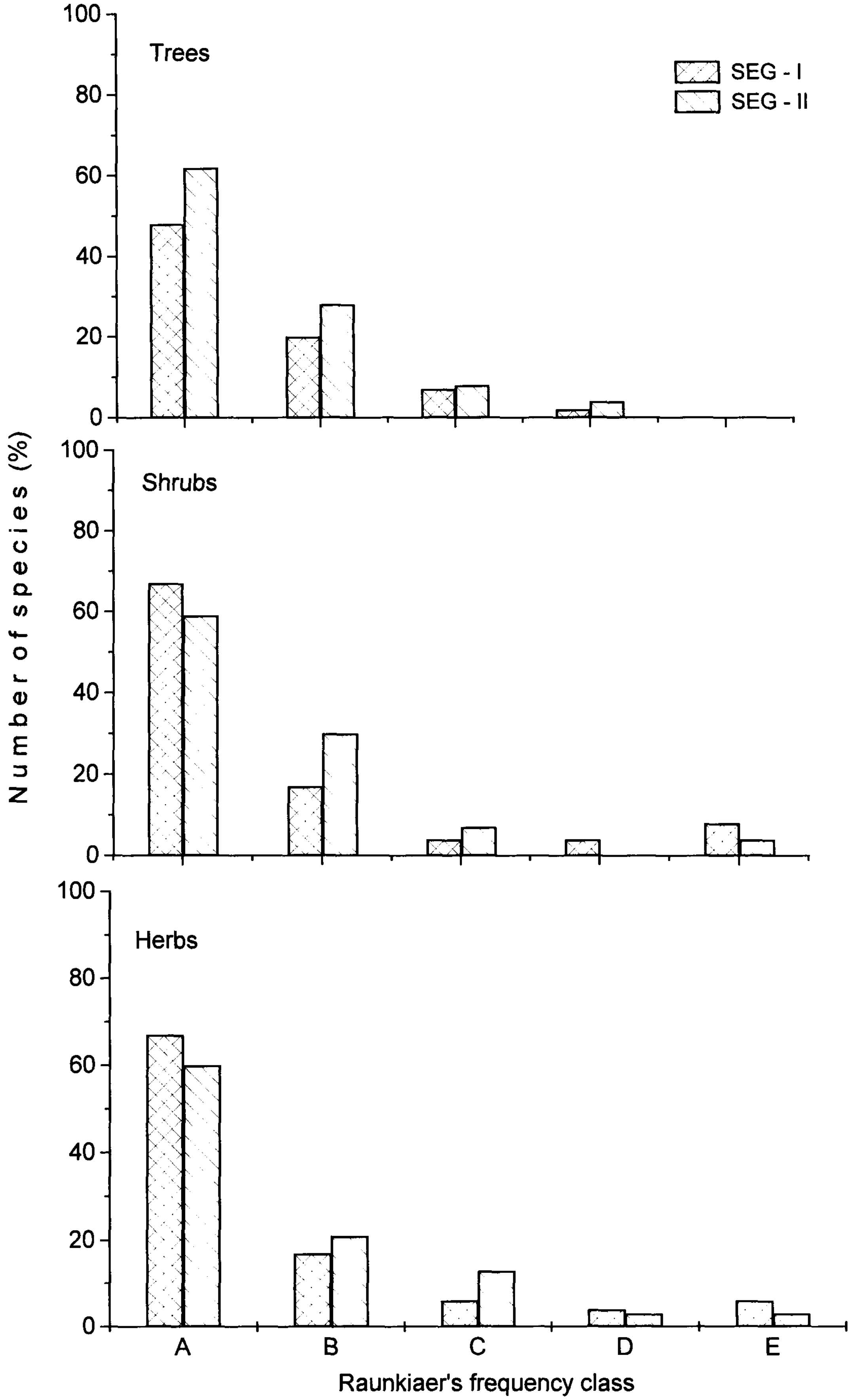


Fig. 6.5. Distribution of plant species in different frequency classes in two stands (SEG-I, SEG-II) of the subtropical semi-evergreen forest.

(<75 cm cbh) contributed 2% and 34.4% to the total stand density in stand SEG-I and II, respectively (Fig. 6.6).

In terms of density *Randia wallichii* (30 individuals ha^{-1}), *Quercus serrata* (28 individuals^{-1}), *Ficus elastica* (23 individuals ha^{-1}), *Ficus oligodon* (23 individuals ha^{-1}), *Schima wallichii* (22 individuals ha^{-1}) and *Helicia nilagirica* (20 individuals ha^{-1}) were dominant in stand SEG-I, and *Salix tetrasperma* (43 individuals ha^{-1}), *Syzygium formosum* (34 individuals ha^{-1}), *S. tetragonum* (24 individuals ha^{-1}), *Daphniphyllum himalayense* (23 individuals ha^{-1}), *Antidesma acidum* (23 individuals ha^{-1}), and *Schefflera glomerata* (22 individuals ha^{-1}) were among the dominant tree species in stand SEG-II.

The total tree basal cover was 25.1 ±1.34 m^2 ha^{-1} in SEG-I and 49.4 ±1.25 m^2 ha^{-1} in SEG-II. Distribution of basal cover and density in different girth-classes followed a reverse trend; the density declined with increasing girth class but the basal cover increased from the lower to higher girth class. The trees of lower girth class (15-35 cm cbh) accounted for 1.4% and 3.1% and those of higher girth class (<75 cm cbh) contributed 82.2% and 5.8% to the total basal cover in SEG-I and II, respectively. In SEG-II middle girth class (35-75 cm cbh) trees contributed more to the basal cover of the stand (Fig. 6.7).

Table 6.6. Mean stand density (individuals ha^{-1}) and mean basal cover (m^2 ha^{-1}) of tree species in the semi-evergreen forest.

	Semi-evergreen forest stands	
	SEG-I	**SEG-II**
Stand density	1063 ±32	838 ±14
Basal cover	33.3 ±0.59	38.8 ±2.22

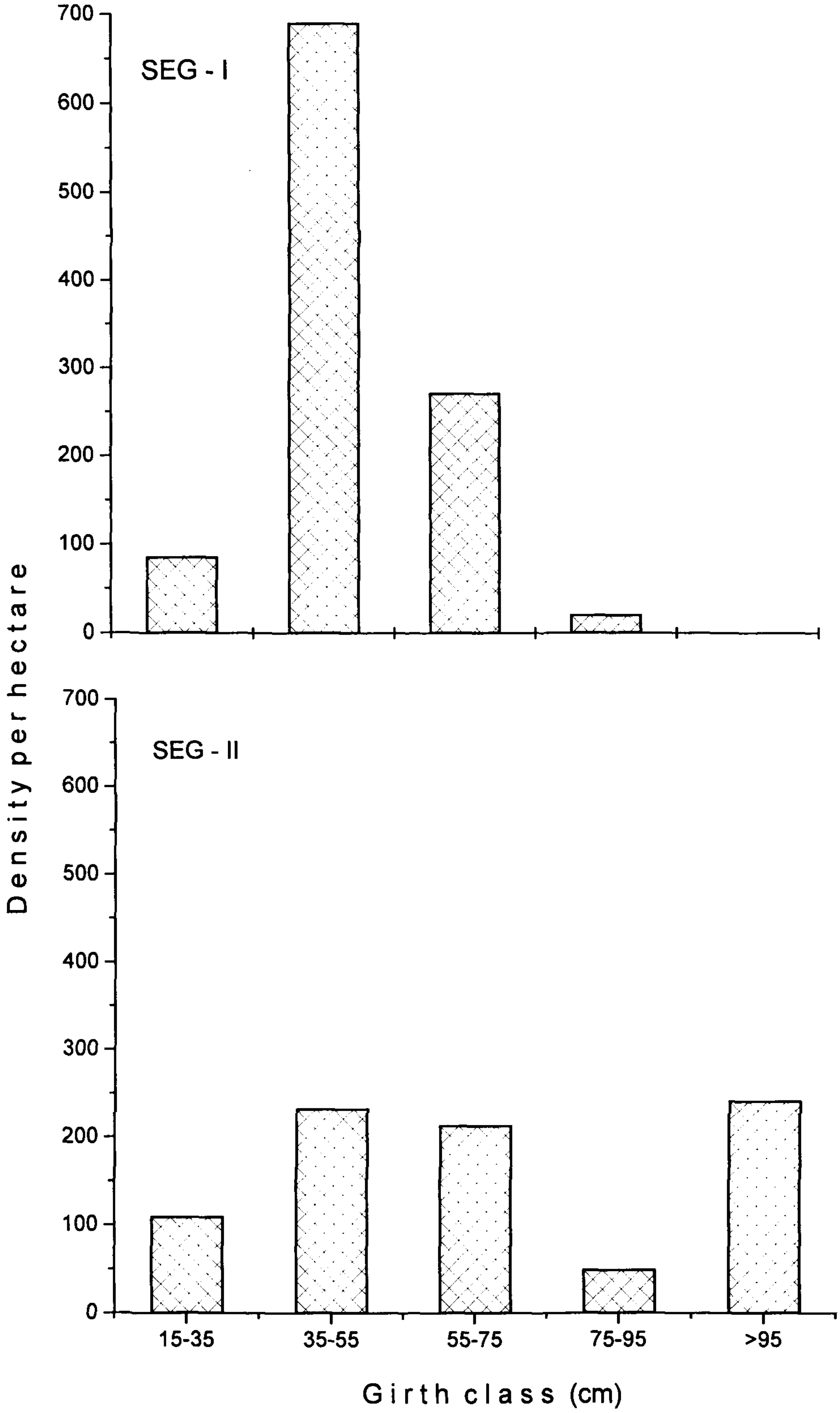


Fig. 6.6. Distribution of tree species in different girth classes in two (SEG-I, SEG-II) stands of the subtropical semi-evergreen forest.

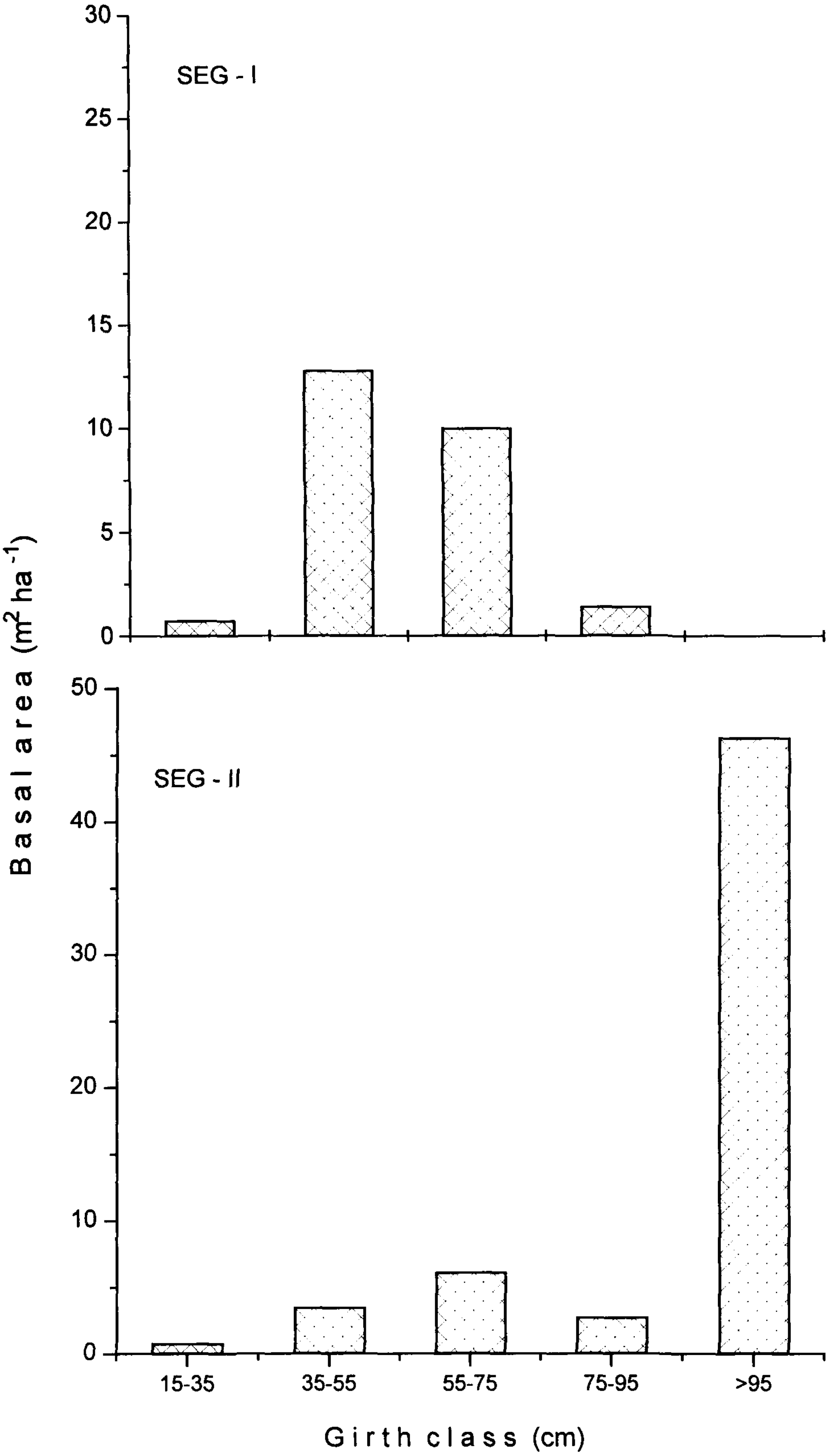


Fig. 6.7. Distribution of tree basal cover in different girth classes in two (SEG-I, SEG-II) stands of the subtropical semi-evergreen forest.

Dominance

In terms of importance value, *Ficus oligodon* (IVI: 8.8), *Ficus elastica* (IVI: 8.7), *Persea duthiei* (IVI: 8.4), *Aporusa oblonga* (IVI: 8.3) and *Randia wallichii* (IVI: 6.7) in stand SEG–I, and *Syzygium formosum* (IVI: 15.3), *Cryptocarya amygdalina* (IVI: 12.3), *Dysoxulum binectaeriferum* (IVI: 11), *Syzigium tetragonum* (IVI: 10.8) and *Salix tetrasperma* (IVI: 10.4) in stand SEG-II were the dominant species. *Actinodaphne obovata* (IVI: 0.6) and *Wendlandia grandis* (IVI: 0.7) with two individuals each, and *Sapium baccatum* (IVI: 0.26), *Symplocos paniculata* (IVI: 0.29) and *S. cochinchinensis* (IVI: 0.29) with single individual each were the least important species (Table 6.1a, 6.2a).

The dominance-distribution curves of the tree species yielded log normal distribution pattern in stand SEG-II, and broken-stick model in stand SEG–I (Fig. 6.8).

Among the shrub species *Psychotria erratica* (IVI: 23.5), *Symplocos paniculata* (IVI: 23.2), *Adenia trilobata* (IVI: 19.2), *Rhus javanica* (IVI: 12.9) and *Achronychia pedunculata* (IVI: 10.4) in stand SEG–I, and *Ardisia griffithii* (IVI: 17.1), *Clerodendrum infortunatum* (IVI: 14.2), *Erythroxylum kunthianum* (IVI: 14.2), *Eupatorium odoratum* (IVI: 14.2) and *Leptodermis griffithii* (IVI: 12) in stand SEG–II were dominant species. *Ixora undulata* (IVI: 1.5), *Pittosporum podocarpum* (IVI: 1.2) and *Ixora roxburghii* (IVI: 1), and *Acanthopanax aculeatum* (IVI: 1.3), *Neillia thyrsiflora* (IVI: 1.2) and *Melastoma nepalensis* (IVI: 0.9) were the least important species (Table 6.1b, 6.2b).

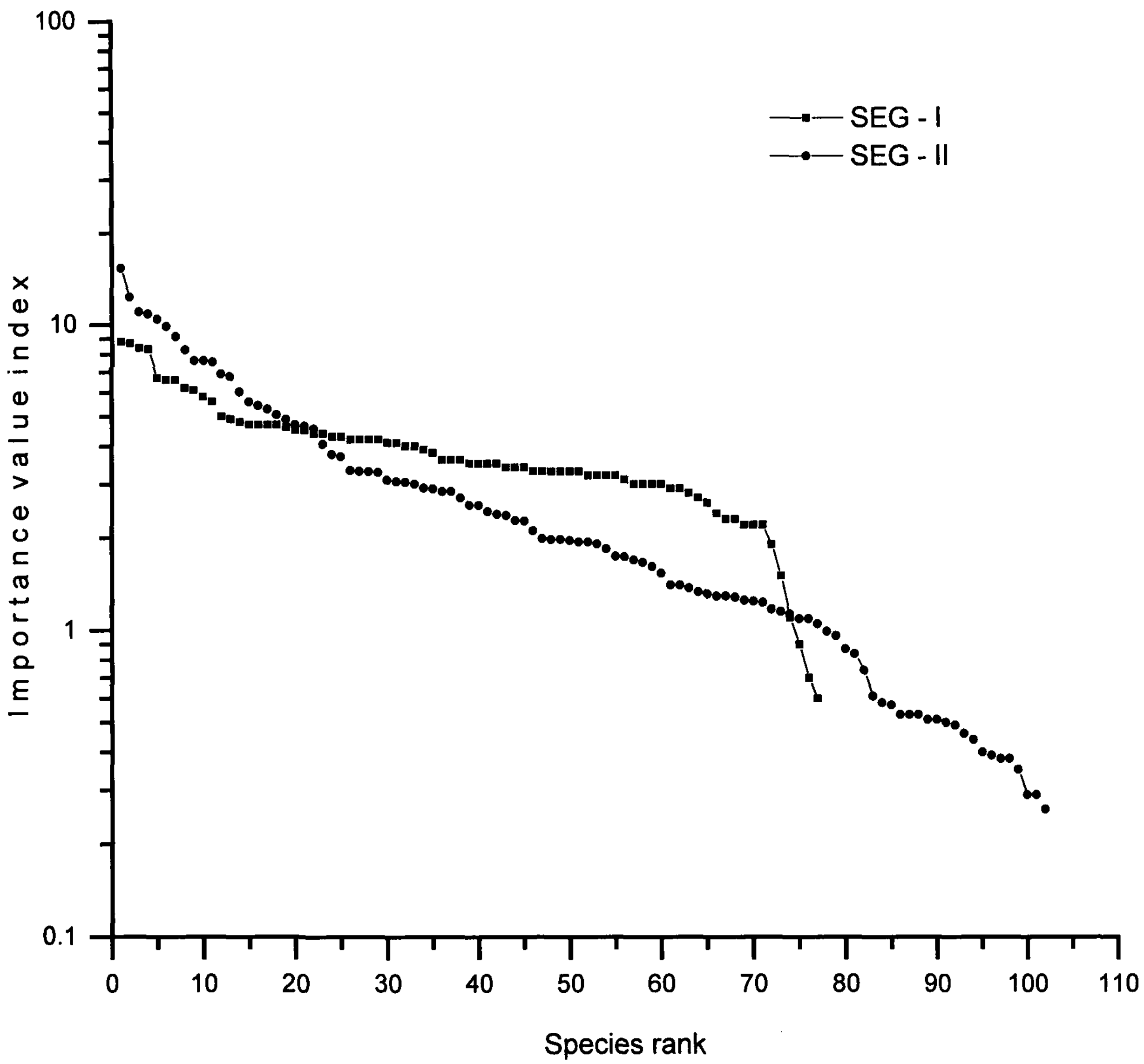


Fig. 6.8. Dominance-diversity curves of tree species (species name and their IVI are given in Table 6.1a, 6.2a) in two stands of subtropical semi-evergreen forest.

The herbaceous layer was dominated by *Anotis oxyphylla* (IVI: 13.8), *Hemiphragma hetrophyllum* (IVI: 13.1), *Davaellia* sp. (IVI: 12.6), *Crysopogon aciculatus* (IVI: 9.9), and *Asplenium* sp. (IVI: 8.4) in stand SEG-I, and by *Andropogon ascinodis* (IVI: 11.4), *Raphidohora decursiva* (IVI: 8.8), *Ophiopogon parviflorus* (IVI: 8.6), *Rubus rugosus* (IVI: 7.4) and *Cymbopogon khasianus* (IVI: 6.8) in stand SEG–II (Table 6.1c, 6.2c).

Similarity and diversity indices

The two stands were quite dissimilar with respect to species composition (Table 6.7). Out of a total of 141 tree species recorded from both the stands, only 37 (26.2%) species were common to the two stands. This resulted in high (0.58 and 0.67) Whittaker's β-diversity index between the two stands.

Table 6.7. Sorensen's similarity (%) index and Whittaker's β-diversity index between the two stands of subtropical semi-evergreen forest.

Index	SEG-I and SEG-II		
	Trees	Shrubs	Herbs
Sorensen similarity index (%)	26.2	19.8	20.1
Whittaker β-diversity index	0.58	0.67	0.66

Different diversity indices such as Shannon diversity, Margalef species richness, Pielou evenness and Simpson dominance index were calculated for the two stands. Tree species diversity in both the stands was higher than the shrubs and herbs, while the dominance index showed a reverse trend (Table 6.8).

Table 6.8. Overall community characteristics of the semi-evergreen forest.

Variables	Stands	
	SEG-I	SEG-II
Trees		
Area sampled (ha)	1.2	1.2
Density ha^{-1}	1063 ±32	838 ±14
Basal cover (m^2 ha^{-1})	25.1 ±1.34	49.5 ±1.25
Species richness	77	102
Number of genera	55	66
Number of families	35	37
Shannon diversity index	4.25	4.21
Margalef species richness index	10.90	14.98
Pielou evenness index	0.98	0.91
Simpson dominance index	0.02	0.02
Shrubs		
Area sampled (m^2)	750	750
Density ha^{-1}	1608 ±56	2145 ±48
Species richness	23	27
Number of genera	20	25
Number of families	13	20
Shannon diversity index	2.91	3.14
Margalef species richness index	3.83	4.11
Pielou evenness index	0.93	0.95
Simpson dominance index	0.06	0.05
Herbs		
Area sampled (m^2)	120	120
Density per 100 m^2	2976 ±56	3013 ±67
Species richness	47	70
Number of genera	40	49
Number of families	25	29
Shannon diversity index	3.55	3.97
Margalef species richness index	5.87	8.56
Pielou evenness index	0.92	0.95
Simpson dominance index	0.03	0.02

Population structure and regeneration of tree species

Density of tree seedling

Mean seedling density (plants 100 m^2) was 1341 ±23 in SEG–I and 926 ±32 in SEG–II. Seedlings of *Cinnamomum tamala*, *Aporusa oblonga*, *Celtis tetranda*, *Callicarpa arborea* and *Ficus racemosa* were common in stand SEG–I, while those of *Elaeocarpus floribundus*, *Garcinia acuminata*, *Daphne shillong*, *Cordia fragrantissima*, *Garcinia cowa* and *Ligustrum robustum* were common in stand SEG–II. In SEG–I seedling density was low in the case of *Cordia grandis*, *Euonymus attenuatus* and *Carralia brachiata* and in SEG–II *Cinnamomum pauciflorum* had few seedlings (Table 6.9a, 6.9b).

Density of tree sapling

The mean sapling (5-15 cm cbh) density was 4056 ±72 and 3380 ±44 individuals ha^{-1} in stand SEG–I and SEG–II, respectively. The saplings of *Glochidion acuminatum*, *Garcinia pedunculata*, *Persea duthiei*, *Eurya acuminata*, *Helicia nilagirica*, *Lindera caudata*, *Celtis tetranda* and *Camellia cauduca* were common in SEG–I, while those of *Citrus medica*, *Eurya acuminata*, *Symplocos javanica*, *Garcinia cowa*, *Ixora undulata*, *Camellia kissi*, *Coffea khasiana* and *Cryptocarya amygdalina* were common in SEG–II. The species like *Lindera latifolia*, *Syzygium cuminii*, *Myrica esculenta* and *Polyalthia simiarum* in SEG–I, and *Litsea cubeba*, *Schima wallichii* and *Prunus nepalensis* in stand SEG–II, had low sapling density (Table 6.10a, 6.10b).

Table 6.9a. Frequency (%), density (per 100 m^2) and importance value index of tree seedlings in stand I of the subtropical semi-evergreen forest.

Name of species	Family	Density	Frequency	IVI
Cinnamomum tamala Fr. Nees.	Proteaceae	127	79	19.6
Aporusa oblonga Muell.-Arg.	Euphorbiaceae	123	72	18.4
Celtis tetrandra Roxb.	Ulmaceae	111	77	18.1
Callicarpa arborea Roxb.	Verbenaceae	110	68	17.0
Ficus racemosa Linn.	Moraceae	113	53	15.3
Combretum acuminatum Roxb.	Combretaceae	86	60	14.1
Beilshmiedia roxburghiana Nees	Lauraceae	84	52	12.9
Dimocarpus longan Lour.	Sapindaceae	85	43	11.9
Coffea khasiana Hk.f.	Rubiaceae	72	49	11.7
Gaultheria fragrantissima Wall.	Ericaceae	54	33	8.2
Brassiopsis glomerulata Bl.	Araliaceae	58	27	7.7
Randia wallichii Hk.f.	Rubiaceae	47	25	6.7
Aporusa aurea Hk.f.	Euphorbiaceae	29	18	4.4
Drypetes assamicus Hk.f.	Euphorbiaceae	28	14	3.9
Cleidion spiciflorum (Burm.) Merr.	Euphorbiaceae	23	15	3.6
Eurya acuminata DC.	Theaceae	23	14	3.5
Actinodaphne ovabata (Nees.) Bl.	Actinidiaceae	29	9	3.3
Lindera latifolia Hk.F.	Lauraceae	29	9	3.3
Helicia nilagirica Bedd.	Proteaceae	18	11	2.7
Camellia caudata Wall.	Theaceae	17	11	2.7
Cordia fragrantissima Kurz.	Boraginaceae	14	8	2.0
Celtis tinorensis Lindl.	Ulmaceae	13	8	1.9
Syzygium cumini Linn.	Myrtaceae	13	8	1.9
Garcinia paniculata (G.Don.)Roxb.	Clausiaceae	12	7	1.7
Cordia grandis Roxb.	Boraginaceae	8	4	1.1
Euonymus attenuatus Laws.	Celastraceae	8	4	1.1
Carralia brachiata (Lour.) Merr.	Cannaceae	7	4	1.1
		1341		**200**

Table 6.9b. Frequency (%), density (per 100 m^2) and importance value index of tree seedlings in stand II of the subtropical semi-evergreen forest.

Name of species	Family	Density	Frequency	IVI
Ardisia griffithii Cl.	Myrsinaceae	41	22.5	8.8
Citrus medica Linn.	Rutaceae	53	14.2	8.5
Daphne shillong Banerzi.	Thymeliaceae	78	30.0	14.3
Eurya acuminata DC.	Theaceae	42	24.2	9.3
Ligustrum robustum Roxb. Bl.	Oleaceae	63	35.0	13.7
Litsea salicifolia (Roxb.ex Nees.) Hk.f.	Lauraceae	35	24.2	8.5
Cinnamomum pauciflorum Nees.	Lauraceae	21	10.8	4.4
Cordia fragrantissima Kurz.	Boraginaceae	68	43.3	15.9
Daphiniphyllum himalayense (Benth.) Muell.-Arg.	Daphniphyllaceae	35	20.0	7.7
Elaeocarpus floribundus Bl.	Elaeocarpaceae	126	71.7	27.7
Nauclea griffithii Hav.	Rubiaceae	41	20.0	8.4
Garcinia cowa Roxb.ex DC.	Clusiaceae	82	64.2	21.5
Persea duthiei King.ex Hk.f.	Lauraceae	63	22.5	11.2
Myrica esculenta (Buch.-Ham.ex D. Don.)	Myricaceae	23	15.8	5.6
Randia longiflora Lamk.	Rubiaceae	31	18.3	6.9
Symplocos paniculata Thunb.	Symplocaceae	47	29.2	10.8
Schima wallichii (DC.) Korth.	Theaceae	19	8.3	3.7
Citrus sp.	Rutaceae	24	14.2	5.4
Ardisia floribunda DC.	Myrsinaceae	34	20.8	7.8
		926		**200**

Table 6.10a. Frequency (%), density (individuals ha^{-1}) and importance value index of tree saplings in stand I of the subtropical semi-evergreen forest.

Name of species	Family	Density	Frequency	IVI
Glochidion acuminatum Muell.-Arg	Euphorbiaceae	364	97	15.6
Garcinia pedunculata G. Don.	Clusiaceae	208	90	10.8
Persea duthiei King. ex Hk.f.	Lauraceae	156	90	10.0
Eurya acuminata (DC.)	Theaceae	182	77	9.5
Helicia nilagirica Bedd.	Proteaceae	182	63	8.8
Lindera caudata Benth.	Lauraceae	182	63	8.5
Celtis tetrandra Roxb.	Ulmaceae	234	40	8.4
Camellia cauduca Brandis.	Theaceae	156	50	7.4
Wrightia coccinea Roxb.	Apocynaceae	130	57	6.9
Glochidion khasicum Hk.f.	Euphorbiaceae	104	57	6.4
Symplocos lucida Thunb.	Symplocaceae	104	57	6.4
Garcinia paniculata (G.Don.)Roxb.	Clusiaceae	104	50	6.1
Persea odoratissima Nees.	Lauraceae	104	47	5.5
Wendlandia wallichii (W. & A.)	Rubiaceae	104	40	5.1
Ficus racemosa Linn.	Fagaceae	78	43	4.8
Agapetes variegata Roxb.	Vaccinaceae	104	27	4.4
Coffea khasiana Hk.f.	Rubiaceae	78	37	4.2
Aquilaria khasiana Hall.	Aquilariaceae	78	30	4.0
Premna latifolia Roxb.	Verbenaceae	78	30	3.9
Ligustrum lucidum Ait.f.	Oleaceae	52	30	3.5
Syzygium tetragonum Wall.	Myrtaceae	52	30	3.5
Cordia fragrantissima Kurz.	Boraginaceae	78	23	3.5
Embelia floribunda Wall.	Myrsinaceae	52	30	3.4
Rhododendron arboreum Sm	Ericaceae	78	17	3.1
Aporusa dioica (Roxb.) Muell.-Arg.	Euphorbiaceae	52	23	3.1
Cinnamomum pauciflorum Nees.	Lauraceae	78	20	3.0
Daphniphyllum himalyense Benth.	Daphniphyllaceae	52	20	2.8
Grewia disperma Spreng.	Tiliaceae	52	23	2.7
Pandanus odoratissimus (Lamk.) Linn.	Pandanaceae	52	23	2.7
Camellia caudata Wall.	Theaceae	52	20	2.6
Randia griffithii Hk.f.	Rubiaceae	52	13	2.4
Schima wallichii Dyer.	Theaceae	52	17	2.2
Actinodaphne obovata (Nees.) Bl.	Actinidiaceae	52	17	2.1
Cinnamomum tamala Fr. Nees.	Proteaceae	52	17	2.1
Engelhardtia spicata Leschen.ex Bl.	Juglandaceae	52	17	2.1
Neolitsea cassia (Linn.) Koster.	Lauraceae	26	17	2.0
Quercus kamroopii D. Don.	Fagaceae	26	13	1.6
Randia wallichii Hk.f.	Rubiaceae	26	10	1.6
Saprosma ternatum Hk.f.	Rubiaceae	26	13	1.5
Rhus acuminata DC.	Anacardiaceae	52	7	1.5
Ligustrum robustum (Roxb.) Bl.	Oleaceae	26	7	1.3
Pyrus pashia D.Don.	Rosaceae	26	10	1.3
Combretum acuminatum Smith	Combretaceae	26	10	1.2
Ligustrum indicum Ait.f.	Oleaceae	26	7	0.8

Meliosma wallichii Hk.f.	Meliaceae	26	7	0.8
Quercus glauca Thunb.	Fagaceae	26	7	0.8
Quercus serrata Thunb.	Fagaceae	26	7	0.8
Sapindus rarak DC.	Sapindaceae	26	7	0.8
Diospyros lancifolia Roxb.	Ebenaceae	26	7	0.7
Syzygium cumini Linn.	Myrtaceae	26	7	0.7
Lindera latifolia Hk.F.	Lauraceae	26	3	0.5
Myrica esculenta Buch.-Ham.ex D. Don.	Myricaceae	26	3	0.5
Polyalthia simiarum Hk.f. & Th.	Annonaceae	26	3	0.3
		4056		**200**

Table 6.10b. Frequency (%), density (individuals ha^{-1}) and importance values index of tree saplings in stand II of the subtropical semi-evergreen forest.

Name of species	Family	Density	Frequency	IVI
Citrus medica Linn.	Rutaceae	380	23	18.7
Eurya acuminata DC.	Theaceae	260	93	14.8
Erythrina stricta Roxb.	Leguminosae	180	30	12.1
Symplocos javanica (Bl.) Kurz.	Symplocaceae	200	80	11.8
Garcinia cowa Roxb ex DC.	Clusiaceae	160	87	11.4
Ixora undulata Roxb.	Rubiaceae	180	70	10.6
Camellia kisii Wall.	Theaceae	180	57	9.6
Coffea khasiana Hk.f.	Rubiaceae	180	53	9.3
Cryptocarya amygdalina Nees.	Lauraceae	160	57	9.1
Ligustrum confusum Linn.	Oleaceae	120	57	7.8
Myrica esculenta Buch.-Ham. ex D. Don	Myricaceae	140	43	7.5
Pyrus pashia D.Don.	Rosaceae	120	43	6.8
Citrus sp.	Rutaceae	100	43	6.5
Capparis assamica Hk.f. &Th.	Capparidaceae	100	37	5.5
Meliosma wallichii Planch.ex Planch	Sabiaceae	80	37	5.1
Combretum latifolium Bl.	Combretaceae	80	17	4.8
Michelia oblonga Wall.	Magnoliaceae	60	17	4.2
Ligustrum robustum Roxb. Bl.	Oleaceae	60	27	4.0
Glochidion khasicum Hk.f.	Euphorbiaceae	60	12	3.9
Symplocos lucida Thunb.	Symplocaceae	60	18	3.8
Glochidion acuminatum Muell.-Arg.	Euphorbiaceae	60	23	3.7
Vitex pinnata Linn.	Verbenaceae	60	23	3.7
Michelia champaca Linn.	Magnoliaceae	60	23	3.4
Persea duthiei King ex Hk.f.	Lauraceae	60	20	3.0
Alangium chinensis Lour.	Cornaceae	60	17	2.9
Persea bombycina King.ex Hk.f.	Lauraceae	60	17	2.9
Sapindus rarak DC.	Sapindaceae	60	17	2.9
Lindera latifolia Hk.f.	Lauraceae	40	20	2.9
Litsea cubeba Lour.	Lauraceae	40	5	2.3
Schima wallichii (DC.) Korth.	Theaceae	40	5	2.3
Prunus nepalensis (Ser.) Steud.	Rosaceae	40	3	2.2
		3380		**200**

Density of adult trees

The density (individuals ha^{-1}) of adult (>15 cm cbh) trees was 1063 ±32 in SEG–I and 838 ±14 in SEG–II (Table 6.6).

The population densities of seedlings, saplings and adult trees formed a pyramidal structure in both the stands. About 27% and 33% seedlings were able to grow up to sapling stage, whereas about 25% saplings could reach to the adult stage. It showed that mortality rates were high (67%-73%) between seedling and sapling stage (Fig. 6.9).

Population structure of dominant species

Ten dominant species in each of two stands were selected on the basis of their contribution to the stand density for studying their population structure. Besides, density of seedlings and saplings, and density-distribution of adult (>15 cm cbh) trees in different girth classes were also considered while selecting the species for studying their population structure.

Populations of *Randia wallichii*, *Helicia nilagirica*, *Ficus racemosa* and *Eurya acuminata* were made up of individuals of most girth classes. In case of *Quercus serrata*, *Eurya japonica*, *Schima wallichii*, *Rhododendron arboreum* and *Persea duthiei* individuals of less than 5 cm cbh were absent. *Ficus elastica* had no tree in lower (<15 cm cbh) girth class but the maximum number of individuals was in the middle girth (35-55 cm cbh) class (Fig. 6.10).

Daphniphyllum himalayense, *Diospyros binectaeriferum*, *Eriobotrya dubia*, *Syzygium formosum*, *S. tetragonum*, *Grewia microcos*, *Schefflera microcos*, *Michelia doltsopa* and *Salix psilostigma* had no young individuals

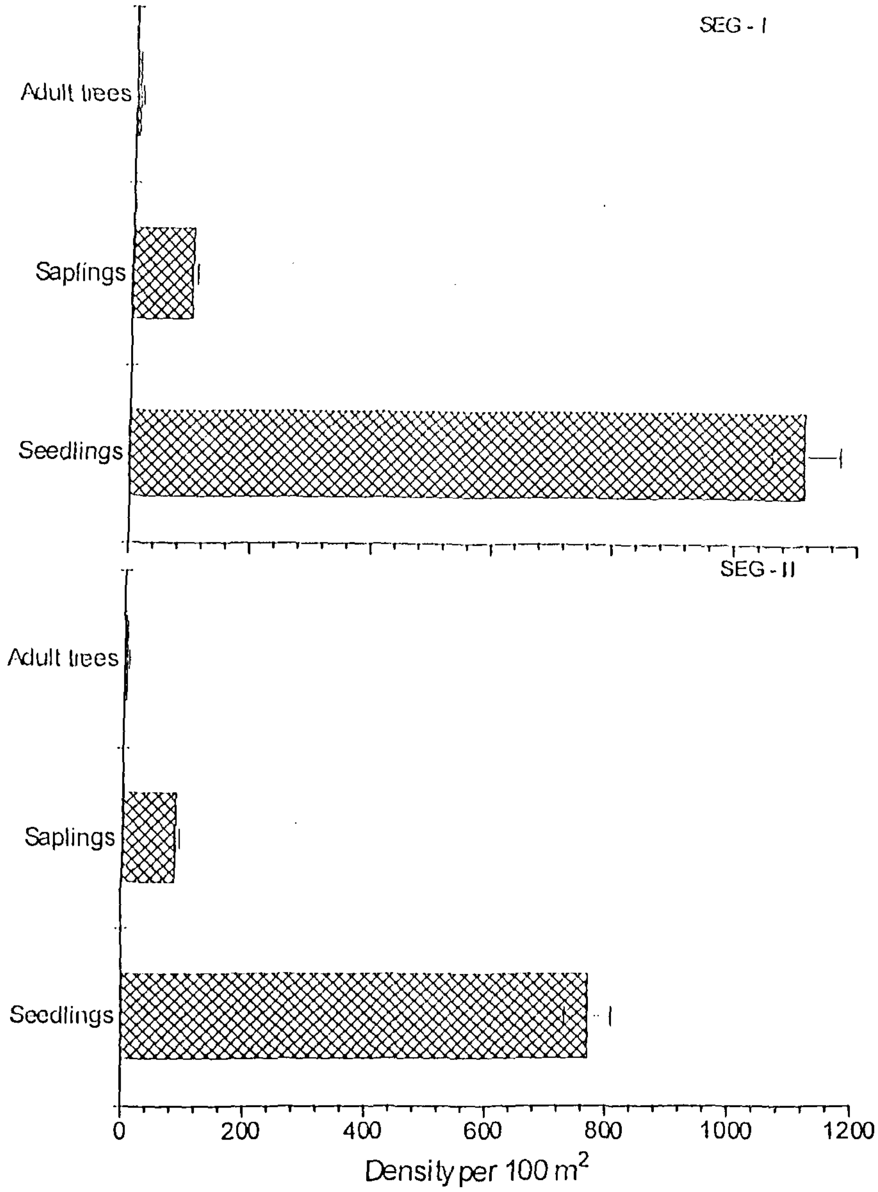


Fig. 6.9. Population density of seedlings, saplings and adult trees in the two stands of semi-evergreen forest.

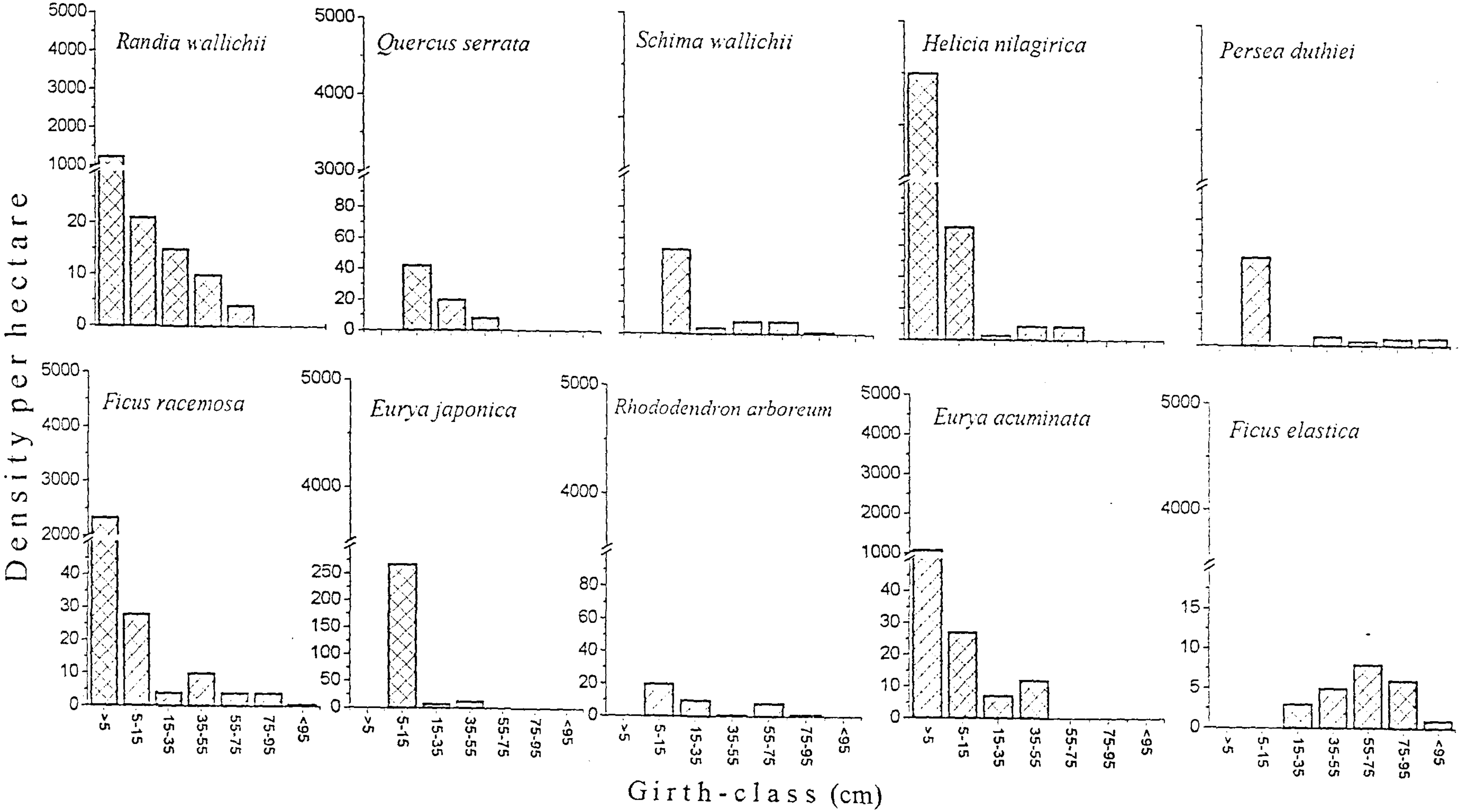


Fig.6.10.Population structure of ten dominant species in subtropical semi-evergreen forest stand (SEG - I).

(<15 cm cbh). In the stand SEG–II; they were represented either by middle (35–55 cm cbh) or higher (>75 cm cbh) girth classes. *Antidesma acidum* was the only species, which had a large number of young individuals (Fig. 6.11).

Discussion

Subtropical semi-evergreen forests of the state of Meghalaya are found between 1200 m and 1800 m asl, where average annual rainfall ranges between 150 cm – 300 cm. The two representative stands (SEG-I and II) under investigation were experiencing certain level of anthropogenic stresses in the form of grazing and collection of timber and fuelwood.

Despite general similarity in the soil and climatic condition, the two stands differed markedly in species richness including tree component, leading to low index of similarity and high β-diversity between the stands. This could be related to the age of the stand and the level of disturbance to which they were exposed. As observed during the study period, stand SEG-I (Mawlong sacred grove) was more disturbed due to frequent grazing and fuelwood collection, while in stand SEG-II (Mawiong sacred grove) these activities were almost absent. The stand SEG-II was older in age, as is evident by the presence of larger number of trees having >95 cm cbh in this stand than the SEG-I where middle girth class (35-55 cm cbh) trees were abundant (Fig. 6.6).

Gentry (1988) has reported 606 individuals representing 300 tree species from 1 hectare plot of tropical rain forest in Peru. Compared to this value, tree species richness (76 and 102 species) obtained in 1.2 ha area is

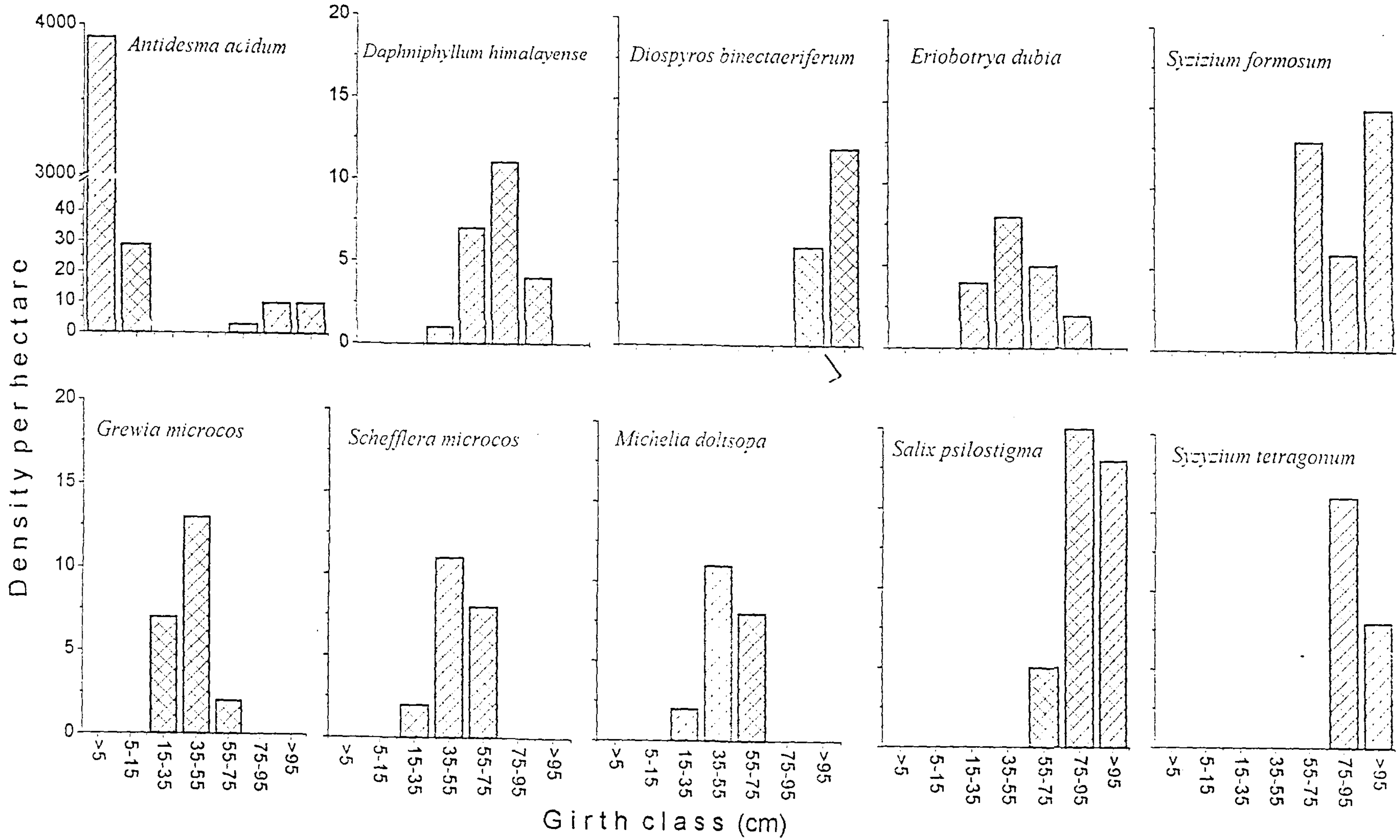


Fig.6.11. Population structure of ten dominant species in subtropical semi-evergreen forest stand (SEG - II).

very low. However, the values are comparable to those reported by Felfili and Maria (1995) from Gamma Gallery (87 species from 3 ha), Aiba and Kitayama (1999) from Mount Kinabalu (121 species from 0.5 ha) and Jamir (2000) from Jaintia hills (135 species from 0.8ha), Meghalaya.

Gentry (1988) and Vazquez and Givnish (1998) have reported that Leguminaceae, Lauraceae, Moraceae, Rubiaceae and Euphorbiaceae were the important families in Amazonian rain forest and in the tropical forests of Sierra de Manantlam. Ayyappan (2002) and Manokaran *et al.* (1991) have also reported dominance of these families in the Western Ghats and in Pasoh reserve forest of Malaysia, respectively. In this respect the two studied forest stands are similar to the abovementioned forests.

The dominance of phanerophytes in both the semi-evergreen forest stands of Meghalaya is indicative of mild and moist climate as has also suggested by Archibold (1995).

Contagious/clumped distribution pattern and low frequency of most species in both the stands was responsible for making the community highly heterogeneous and patchy. Armesto *et al.* (1986) compared the dispersion pattern of trees in the tropical and temperate climates in different parts of the world and concluded that clumping was the dominant characteristics of those forests in which formation of canopy gaps was the chief source of disturbance. Whitmore (1990) has described tropical rain forests as highly patchy community primarily due to gap phase dynamics. This type of distribution of species is often related to inefficient mode of seed dispersal (Richards 1996). Regular distribution pattern may be the consequence of direct competition for water or allelopathy (MacMohan and Schimpf 1981). Random distribution of species in the community is a sign of frequent disturbance (Armesto *et al.* 1986). It is worth noting that in stand SEG-I which was subjected to greater level of disturbance compared to SEG-II, where 23% to 32% of the species were randomly distributed.

The dominance-distribution curves, which signify equitability and stability of the community, changed from lognormal in the protected stand SEG-II to broken-stick type in stand SEG-I which was disturbed. Lognormal distribution signifies abundance of species having intermediate dominance values in the community (Magurran 1988) and indicates maturity and complexity of natural community. The broken-stick distribution pattern reflects that the community is primarily ordered in respect of one dominating factor (May 1975).

Comparatively higher density of tree species in stand SEG-I (1063 ±32 stem ha^{-1}) than in SEG-II (838 ±14 stem ha^{-1}) was primarily due to disturbance which was responsible for removal of large trees from the latter stand leading to creation of large number of favourable micro-sites for better tree regeneration in SEG-I. The tree density at the two study sites is comparable to the values reported by Pelissier and Riera (1993) in French Guyana (1168 stem ha^{-1}), Strasberg (1996) in France (1079 stem ha^{-1}), Parathasarathy and Karthikeyan (1997) in Thirumanikkuzhi, Western Ghats (974 stem ha^{-1}), Bunyavezchewin (1999) in Thailand (1168 stem ha^{-1}), and Jamir (2000) and Upadhaya *et al.*

(2002) in Jaintia hills district of Meghalaya (1070 stem ha^{-1} and 938-1476 stem ha^{-1}, respectively).

The tree basal cover obtained in the present study is also comparable with the results of Campbell *et al.* (1986) from Terrafirme (27.6-32 m^2 ha^{-1}), Campbell *et al.* (1992) from Brazilian Amazon (25.5-27 m^2 ha^{-1}), Pascal and Pelissier (1996) from Uppangala (39.7 m^2 ha^{-1}), Kadavul and Parathasarathy (1996) from Western Ghats (25.8-41.2 m^2 ha^{-1}), and Upadhaya *et al.* (2002) from sacred groves of Jaintia hills, Meghalaya (36-72 m^2 ha^{-1}). The protected older stand (SEG-II) had greater basal cover than the young and moderately disturbed stand SEG-I, primarily due to the presence of large old trees in the former stand.

The large population of young individuals in most of the tree species of stand SEG-I suggests better tree regeneration in this stand, while the poor density or sometimes complete absence of seedlings in SEG-II was the reflection of the unfavourable condition in this stand. The poor regeneration in SEG-II could be attributed mainly to the dense overhead canopy that significantly reduces the light intensity on the forest floor (2150 lux or 28% of the outside forest). In undisturbed humid tropical humid forests tree regeneration is largely dependent upon the response of the seedlings and saplings to the forest microenvironment and interactive influence of an array of biotic and abiotic factors. Greater number of seedlings in the forest stands is mainly due to favourable micro-sites (Barik *et al.* 1992, Jamir 2000). The sparse canopy cover due to the absence of large old trees in stand SEG-I, allows sufficient light to reach the forest floor which helps in better regeneration of the light demanding species. The sub-canopy species such as *Randia wallichii*, *Helicia nilagirica*, *Ficus racemosa* and *Eurya acuminata* showed better regeneration in stand SEG-I, indicating that they could be the light demanding species. Poor regeneration in majority of the dominant species in SEG-II could be attributed to dense over-head canopy in this stand. *Antidesma acidum* which showed good regeneration in this stand, could be regarded as a shade tolerant species.

CHAPTER VII

Community Structure of Subtropical Pine forest

Khasi pine (*Pinus kesiya* Royle ex Gordon.) is distributed throughout the northeast India except in Assam and Tripura. It grows mostly on the hills of this region. Besides, it is also distributed in Philippines (between 450m – 2450m asl), upper Burma (between 800 m–1900 m asl), Yunnan and north Thailand and Malay Archipelago (Kowal 1966). The trees are generally, 30m to 35 m tall with straight, cylindrical bole. Bark is thick, dark brown, with deep longitudinal fissures and in older stems variously furrowed and plated.

In wet subtropical strongly seasonal climate with a distinct dry and wet seasons, it usually grows as pure stand or mixed with broad-leaved trees on moderately sloping hillsides between 800 m to 2,000 m asl. It is a frost-tolerant species and can grow on well-drained nutrient- poor soils. In the virgin forest, pine trees are restricted to steep, stony ridges with usually podzolic well-drained soils, and landslides, all of which they colonize as typical pioneers. Its natural regeneration is best on mineral soils. Being a shade-intolerant pioneer species, it colonizes landslides and is favoured by fire (Champion 1936, Stainton 1972).

Most pines are fire-adapted, and so is *P. kesiya*. Seedlings are fairly resistant to fire once over 3 m tall, and mature trees are immune to fire damage owing to their extremely thick outer bark. However, short cycles of shifting cultivation and regular annual fire prevent satisfactory regeneration and can lead to the elimination of pine (Colling 1968).

In the state of Meghalaya *P. kesiya* is confined to higher reaches (>800 m asl) of Shillong plateau in Khasi and Jaintia hills, in a narrow belt running in east-west direction. It forms either a pure stand or mixed stand with broad-leaved elements like *Quercus* sp., *Schima wallichii, Rhododendron arboreum* and *Exbucklandia populnea*. During rainy season there is profuse herbaceous undergrowth in the pine forest. However, much of the ground flora lies dormant during winter, giving a barren look to the forest floor.

Age-old practice of shifting cultivation and other anthropogenic activities such as cutting of trees for timber and construction of building, and collection of fuelwood during the past several decades have destroyed the climax subtropical broad-leaved forests at higher elevation in Meghalaya and elsewhere in northeast India, paving the way for invasion and successful growth of *P. kesiya*. According to Puri *et al.* (1989), Khasi pine was introduced in this region in pre-historic times.

The subtropical pine forest, which develops following degradation of subtropical evergreen and semi-evergreen forest persists as stable preclimax community in northeast India. This chapter analyses plant diversity, community characteristics, the distribution of pine as well as other trees in different girth classes and regeneration pattern of pine in three *P. kesiya* stands located along an altitudinal gradient from about 1000m to 2000m asl in the state.

Plant diversity

The forest canopy was almost exclusively composed of pine trees in all the three stands. However, a few trees of broad-leaved species like, *Quercus* sp., *Schima wallichii, Myrica esculenta, Rhododendron arboreum* and *Exbucklandia populnea* were found scattered in these forests. The latter two species were more abundant and conspicuous in the stand P-III. The shrub species growing in the pine forest stands included *Rubus ellipticus*, *R. khasianus, Myrsine semiserrata*, *Osbeckia crinita*, *Nellia thyrsiflora*, *Phyllanthus deblis, Viburnum foetidum* and *Leptodermis* sp. The forest floor was covered with a large number of annual and perennial flowering plants, tree seedlings, saplings and ferns during monsoon. *Lindenbergia hispida, Paspalum* sp., *Ophiopogon wallichii, Hedychium coccineum, Rubus monogynus, Senecio cappa, Lindenbergia racemosa, Galinsoga parviflora* and *Melastoma malabathricum* were common species of the ground vegetation.

Altogether (including tree seedlings and saplings in all the three stands) 174 species belonging to 139 genera and 77 families were recorded from the three stands. The stand P-III had the highest number of species (134 species) followed by P-I (93 species) and P-II (54 species). The proportion of tree species was 40% in stand P-III, 37% in stand P-II and 24% in stand P-I, while that of the shrub species was 22%, 26% and 28%, respectively. The contribution of ground flora to total species richness was 37% to 38% in stands P-II and P-III, and 48% in stand P-I. The forest canopy was composed of 5 species in P-III, while those of stands P-I and P-II had only 1 and 2 tree species, respectively. Similarly the species richness in the shrubs was also higher in stand P-III than the other two stands while herbaceous richness was higher in stand P-II as compared to the other two stands.

Nine (9) tree species belonging to 8 genera and 8 families, 9 plant species belonging to 8 genera and 8 families, and 26 species from 23 genera and 17 families were recorded from stands P-I, P-II and P-III, respectively (Table 7.1a, 7.2a, 7.3a).

Shrubs were represented by 12, 9 and 21 species from 11, 8 and 18 genera, and 9, 6 and 14 families from stands P-I, P-II and P-III, respectively (Table 7.1b, 7.2b, 7.3b). Herbaceous layer was composed of 59 species from 47 genera and 30 families in the stand P-I, 26 species belonging to 25 genera and 17 families in the stand P-II, and 57 species from 49 genera and 28 families in stand P-III (Table 7.1c, 7.2c, 7.3c).

Community structure

Vertical structure

Profile diagrams were drawn by laying the transects of 30 m long and 5 m wide, and all the plants having the cbh >15 cm were considered for preparing the diagram. Profile diagrams show that the canopy is almost exclusively composed of pine trees in stands P-I and P-II, except few scattered trees like *Schima wallichii* and *Lyonia ovalifolia*. There was no clear stratification in these two forest stands (Fig. 7.1, Fig. 7.2). Profile diagram of stand P-III showed that canopy layer is composed of pine trees along with other broad-leaved species like *Rhododendron arboreum*, *Exbucklandia populnea*, *Beilshmiedia*

Table 7.1a. Density (individual ha^{-1}), basal cover (m^2 ha^{-1}), importance value index and distribution pattern of tree species in stand P-I of the subtropical pine forest.

Name of species	Family	Density	Basal cover	IVI	*Distribution pattern
Pinus kesiya Royle. ex Gordon	Pinaceae	850	26.8	215.3	C
Schima walichii (DC.) Korth.	Theaceae	40	0.8	23.3	C
Quercus glauca Thunb.	Fagaceae	20	0.2	13	C
Callicarpa arborea Roxb.	Verbenaceae	17	0.2	13	C
Rhus acuminata Linn.	Anacardiaceae	23	0.2	12.8	C
Litsea salicifolia (Roxb.ex Nees) Hk. f.	Lauraceae	20	0.3	9.2	C
Cassia alata Linn.	Caesalpiniaceae	23	0.2	4.7	C
Quercus serrata Thunb.	Fagaceae	3	0.1	4.4	C
Melia dubia Cav.	Meliaceae	3	0.1	4.3	C
		1000	**28.9**	**300**	

*c= Contagious distribution pattern

Table 7.2a. Density (individual ha^{-1}), basal cover (m^2 ha^{-1}), importance value index and distribution pattern of tree species in stand P-II of the subtropical pine forest.

Name of species	Family	Density	Basal cover	IVI	*Distribution pattern
Pinus kesiya Royle. ex Gordon.	Pinaceae	557	27.66	188.8	C
Schima wallichii (DC.) Korth	Theaceae	93	2.01	33.4	Ra
Quercus semiserrata Roxb.	Fagaceae	57	1.36	29.4	Re
Myrica esculenta Buch.-Ham ex D. Don.	Myricaceae	47	0.97	19.7	C
Albizia chinensis (Osb.) Merr.	Mimosaceae	17	0.63	7.6	C
Quercus glauca Thunb.	Fagaceae	13	0.23	7.2	C
Litsea salicifolia (Roxb.ex Nees) Hk.f.	Lauraceae	13	0.1	6.8	C
Glochidion acuminatum Muell.-Arg.	Euphorbiaceae	10	0.14	5.3	C
Rhus acuminata DC.	Anacardiaceae	3	0.02	1.7	C
		810	**33.13**	**300**	

*c= Contagious, Re= Regular, Ra= Random distribution pattern.

Table 7.3a. Density (individual ha^{-1}), basal cover (m^2 ha^{-1}), importance value index and distribution pattern of tree species in stand III of the subtropical pine forest.

Name of species	Family	Density	Basal cover	IVI	*Distribution pattern
Pinus kesiya Royle. ex Gordon.	Pinaceae	497	27.9	146.7	Ra
Rhododendron arboreum Sm.	Ericaceae	113	3.7	28.1	C
Myrica esculenta Buch.-Ham. Ex D.Don	Myricaceae	50	1.08	17.6	Ra
Quercus glauca Thunb.	Fagaceae	40	0.39	9.8	C
Lyonia ovalifolia (Wall.) Druce.	Ericaceae	33	0.26	8	C
Schima wallichii (DC.) Korth.	Theaceae	27	0.47	7.9	C
Alnus nepalensis D. Don	Betulaceae	27	0.57	7.4	C
Litsea salicifolia (Roxb.ex Nees) Hk.f.	Lauraceae	27	0.29	6.6	C
Rhus javanica Linn.	Anacardiaceae	23	0.21	6.1	C
Randia fasciculata DC.	Rubiaceae	23	0.19	6	C
Diospyros montana Roxb.	Ebenaceae	27	0.25	5.7	C
Glochidion acuminatum Muell.-Arg.	Euphorbiaceae	13	0.07	5.6	Ra
Rhus acuminata Linn.	Anacardiaceae	17	0.13	5.2	C
Erythrina stricta Roxb.	Leguminosae	17	0.07	5.1	C
Psychotria adenophylla Wall.	Rubiaceae	20	0.2	4.9	C
Grewia multiflora Juss.	Tiliaceae	17	0.42	4.4	C
Engelhardtia spicata Leschn.ex Bl.	Juglandaceae	10	0.09	3.7	C
Beilshmiediabrandisii Hk. f.	Lauraceae	13	0.24	3.6	C
Quercus griffithii Hk.f. & Th.ex DC.	Fagaceae	7	0.42	3.4	C
Pyrus pashia D. Don.	Rosaceae	10	0.21	3.2	C
Viburnum odoratissimum Ker.	Caprifoliaceae	10	0.06	2.8	C
Exbucklandia populnea (R.Br.ex Griff.) R.W.Br.	Hamamelidaceae	10	0.06	2.8	C
Eurya acuminata DC.	Theaceae	10	0.05	1.9	C
Lindera latifolia Hk.f.	Lauraceae	3	0.05	1.3	C
Litsea khasyana Miessn.	Lauraceae	3	0.02	1.2	C
Persea duthiei King.ex Hk.f.	Lauraceae	3	0.04	1.2	C
		1050	**37.42**	**300**	

*c= Contagious and Ra= Random distribution pattern

Table 7.1b. Density (individuals ha^{-1}), frequency (%) and importance value index of shrub species in stand I of the pine forest.

Name of species	Family	Density	Frequency	IVI
Phoenix humilis Royle.	Arecaceae	427	37	44.6
Melastoma malabathricum Linn.	Melastomataceae	347	30	36.4
Lantana camara Linn.	Verbenaceae	227	30	29.5
Thysanolaena maxima (Roxb.) O. Ktze.	Poaceae	147	23	21.2
Eupatorium adenophorum Spreng.	Asteraceae	147	17	17.6
Bridelia monoica Lour.	Euphorbiaceae	133	10	13.2
Cassia alata Linn.	Caesalpiniaceae	53	10	8.5
Bridelia stipularis Bl.	Euphorbiaceae	67	7	7.5
Neillia thyrsiflora D. Don.	Meliaceae	67	7	7.5
Phyllanthus deblis Wild.	Euphorbiaceae	53	7	6.7
Clerodendrum viscosum Vent.	Verbenaceae	40	3	4.1
Syzygium cumunii (Linn.) Skeels.	Myrtaceae	27	3	3.4
		1733		**200**

Table 7.2b. Density (individual ha^{-1}), frequency (%) and importance value index of shrub species in stand II of the pine forest.

Name of species	Family	Density	Frequency	IVI
Melastoma malabathricum Linn.	Melastomataceae	542	77	52.5
Eupatorium adenophorum Spreng.	Asteraceae	433	90	50.9
Lantana camera Linn.	Verbenaceae	300	13	31.4
Osbeckia chinensis Linn.	Melastomataceae	283	40	27.4
Rubus ellipticus Sm.	Rosaceae	217	17	25.9
Phyllanthus deblis Willd.	Euphorbiaceae	33	7	3.8
Thysanolaena maxima (Roxb.) O. Ktze.	Poaceae	33	7	3.8
Clerodendrum viscosum Vent.	Verbenaceae	25	3	2.4
Thysanolaena agrostis Nees.	Poaceae	17	3	1.9
		1883		**200**

Table 7.3b. Density (individual ha^{-1}), frequency (%) and importance value index of shrub species in stand III of the pine forest.

Name of species	Family	Density	Frequency	IVI
Eupatorium adenophorum Spreng.	Asteraceae	480	87	43.3
Osbeckia crinita Naud.	Melastomataceae	413	73	37.0
Thysanolaena agrostis Nees.	Poaceae	253	53	24.5
Rubus lasiocarpus Sm.	Rosaceae	173	67	23.3
Rubus ellipticus Sm.	Rosaceae	127	43	15.8
Phyllanthus deblis Willd.	Euphorbiaceae	107	33	12.7
Elaeagnus latifolia Linn.	Elaeagnaceae	87	20	8.8
Erythrina stricta Roxb.	Leguminosae	53	17	6.3
Glochidion lanceolarium (Roxb.) Voigt.	Euphorbiaceae	53	13	5.6
Emblica officinalis Gaertn.	Euphorbiaceae	27	13	4.2
Litsea salicifolia (Roxb.ex Nees.) Hk.f.	Lauraceae	40	7	3.5
Rubus lucens Foche.	Rosaceae	33	7	3.1
Mussaendra roxburghii Hk.f.	Rubiaceae	20	3	1.7
Daphne papyracea Wall.	Thymeliaceae	13	3	1.4
Hypericum uralum Buch.-Ham.ex D. Don.	Hypericaceae	13	3	1.4
Milletia pachycarpa Benth.	Fabaceae	13	3	1.4
Randia longiflora Lamk.	Rubiaceae	13	3	1.4
Viburnum foetidum Wall.	Caprifoliaceae	13	3	1.4
Colquinea coccinea Wall.	Lamiaceae	7	3	1.1
Neillia thyrsiflora D. Don.	Rosaceae	7	3	1.1
Phyllanthus urinaria Linn.	Euphorbiaceae	7	3	1.1
		1953		**200**

Table 7.1c. Density (individual 100 m^2), frequency (%) and importance value index of herbaceous species in stand I of the pine forest.

Name of species	Family	Density	Frequency	IVI
Rubia cordifolia Linn.	Rubiaceae	144	93	17.5
Desmodium racemosum (Thunb.) DC.	Fabaceae	140	73	15.3
Areca gracilis Roxb.	Arecaceae	183	37	14.5
Asplenium sp.	Aspleniaceae	140	48	12.9
Eleusine corocana (Linn.) Gaertn	Poaceae	73	64	10.5
Pouzolzia latifolia Roxb.	Urticaceae	71	63	10.2
Pteris sp.	Pteridaceae	68	56	9.4
Paspalum orbiculare Fr.	Poaceae	68	52	9.0
Dioscoria bulbifera Linn.	Dioscoreaceae	50	49	7.7
Inula cappa (Buch.-Ham.ex D.Don) DC.	Asteraceae	50	49	7.7
Gleichenia sp.	Glecheniaceae	50	46	7.3
Crotalaria assamica Benth.	Fabaceae	53	43	7.2
Rubus khasianus Cordot.	Rosaceae	64	31	6.8
Cymbopogon khasianus Duthie	Poaceae	57	23	5.5
Lygodium sp.	Schizaeaceae	36	33	5.2
Panicum humidorum Hk.f.	Poaceae	36	29	4.9
Colquhounia coccinea Wall.	Lamiaceae	29	27	4.3
Galinsoga parviflora Cav.	Asteraceae	31	24	4.1
Costus speciosus (Koenig) Smith	Zingiberaceae	23	22	3.4
Molineria capitulata (Lour.)	Hypoxidaceae	25	18	3.2
Dioscoria glabra Roxb.	Dioscoreaceae	21	18	3.0
Peperomia pellucida (Linn.) HBK.	Piperaceae	23	16	2.8
Hedychium coccineum Smith	Zingiberaceae	23	14	2.7
Desmodium triangulare (Reitz.) Merr.	Fabaceae	23	12	2.4
Tacca laevis Roxb.	Taccaceae	15	11	1.9
Mimosa pudica Linn.	Mimosaceae	13	10	1.7
Senecio cappa Buch.-Ham. Ex D. Don.	Asteraceae	12	7	1.3
Senecio scandens D. Don	Asteraceae	14	4	1.2
Goldfussia glabrata Nees.	Acanthaceae	8	8	1.2
Ophiorrhiza nutans Clarke.	Rubiaceae	8	8	1.2
Sonerila khasiana Clarke	Melastomataceae	10	6	1.1
Cynotis barbata D. Don	Commelianiaceae	9	6	1.1
Gerbera maxima Benth.	Asteraceae	9	5	1.0
Digitaria cruciata (Steud.) A. Camus.	Poaceae	7	5	0.9
Elsholtzia blanda Benth.	Lamiaceae	8	3	0.8
Dioscoria hispida Dennst.	Dioscoreaceae	5	4	0.7
Diosporum calcaratum D. Don.	Liliaceae	4	4	0.6
Viola sikkimensis Wt.	Violaceae	4	4	0.6
Sonchus oleraceus Linn.	Asteraceae	8	2	0.6
Itea macrophylla Wall.	Iteaceae	7	3	0.6
Smilax lanceifolia Roxb.	Smilacaceae	3	4	0.6
Piper grffithii C. DC.	Piperaceae	7	2	0.5
Zingeber rubens Roxb.	Zingiberaceae	5	3	0.5
Sonerila maculata Roxb.	Melastomataceae	4	3	0.5
Digitaria ciliaris (Reitz.) Koel.	Poaceae	3	3	0.5
Artemisia nilagirica Cl.	Asteraceae	3	2	0.4

Scirpus juncoides Roxb.	Cyperaceae	3	2	0.4
Smilax ferox Kunth.	Smilacaceae	3	2	0.4
Viola palmaris Ging.	Violaceae	3	2	0.4
Hodgsonia macrocarpa Bl.	Passifloraceae	3	2	0.3
Leea crispa Linn.	Leeaceae	3	2	0.3
Premna barbata Wall. ex Sch.	Verbenaceae	3	2	0.3
Cyperus compressus Linn	Cyperaceae	2	2	0.2
Digitaria longiflora Reitz.	Poaceae	2	2	0.2
Smythea macrocarpa Hemsl.	Fabaceae	2	1	0.2
Cyperus digitatus Roxb.	Cyperaceae	1	1	0.1
Cyperus pilosus Vahl.	Cyperaceae	1	1	0.1
Hoya lanceolata Wall. ex D. Don.	Asclepiadaceae	1	1	0.1
Premna latifolia Roxb.	Verbenaceae	1	1	0.1
		1669		**200**

Table 7.2c. Density (individual 100 m^2), frequency (%) and importance value index of herbaceous species in stand II of the pine forest.

Name of species	Family	Density	Frequency	IVI
Pteris sp.	Pteridaceae	177	65	18.2
Potentilla fulgens Wall.	Rubiaceae	129	93	17.8
Imperata cylindrica (Linn.) P. Beauv.	Poaceae	107	82	15.2
Gleichenia sp.	Glecheniaceae	93	77	13.7
Commelina sikkimensis Clarke.	Commelianiaceae	88	75	13.2
Anaphalis griffithii Hk. f.	Asteraceae	78	79	13.0
Asplenium sp.	Aspleniaceae	86	58	11.5
Eleusine corocana (Linn.) Gaertn	Poaceae	64	13	11.3
Hedychium coccineum Smith	Zingiberaceae	78	13	11.2
Paspalum orbiculare Forst.	Poaceae	73	11	10.8
Panicum humidorum Hk.f.	Poaceae	114	8	10.5
Pouzolzia zeylanica Linn.	Urticaceae	64	7	9.7
Curcuma angustifolia Roxb.	Zingiberaceae	54	43	7.9
Cyperus pilosus Vahal.	Cyperaceae	61	29	7.0
Desmodium racemosum (Thunb.) DC.	Fabaceae	47	37	6.7
Eriosema chinense (non Vogel.) Baker	Fabaceae	57	29	6.7
Vaccinium griffithianum Wt.	Vaccinaceae	30	13	3.2
Zingeber rubens Roxb.	Zingiberaceae	18	19	3.0
Breynia retusa (Dennst.) Alst.	Euphorbiaceae	19	13	2.6
Peperomia pellucida (Linn.) HBK.	Piperaceae	13	6	1.4
Sonchus radigatum Linn.	Asteraceae	10	8	1.4
Viola sikkimensis W.	Violaceae	9	8	1.3
Commelina beghalensis Linn.	Commelinaceae	7	7	1.1
Eulalia pallens Hack.	Poaceae	8	3	0.8
Rubus rugosus Sm.	Rosaceae	4	2	0.4
Oxalis corniculata Linn.	Oxallidaceae	3	2	0.3
		1490		**200**

Table 7.3c. Density (individual 100 m²), frequency (%) and importance value index of herbaceous species in stand III of the pine forest.

Name of species	Family	Density	Frequency	IVI
Asplenium sp.	Aspleniaceae	130	79	18.8
Davaellia sp.	Davalliaceae	78	77	14.6
Eriosema chinense (non Vogel) Baker	Fabaceae	78	52	11.8
Commelina sikkimensis Clarke.	Commelianiaceae	57	58	11.0
Berbaris wallichiana DC.	Berberidaceae	63	52	10.6
Panax pseudoginseng Wall.	Araliaceae	93	23	9.5
Cissampelos pareira Linn.	Menispermaceae	58	28	7.6
Eragrostis nigra Nees ex Steud.	Poaceae	53	28	7.2
Hedychium coccineum Smith	Zingiberaceae	43	32	6.8
Duchesnea indica (Andr.) Focke	Rosaceae	61	20	6.8
Galinsoga parviflora Cav.	Asteraceae	36	32	6.3
Smilax lanceifolia Roxb.	Smilacaceae	30	27	5.3
Cymbopogon khasianus Duthie	Poaceae	39	20	5.2
Cynotis barbata D. Don	Commelianiaceae	27	26	4.9
Ophiopogon parviflorus (Hook) f. Hara.	Liliaceae	29	23	4.8
Gerbera maxima Benth. & Hk.f.	Asteraceae	34	19	4.7
Rubus rugosus Sm.	Rosaceae	28	22	4.5
Vitis latifolia Roxb.	Vitaceae	23	23	4.4
Crysopogon aciculatus Reitz.	Poaceae	28	19	4.3
Andropogon ascinodes C.B.Cl.	Poaceae	27	20	4.3
Eleusine corocana (Linn.) Gaertn	Poaceae	28	13	3.6
Rubia cordifolia Linn.	Rubiaceae	23	16	3.5
Elsholtzia blanda Benth.	Lamiaceae	23	14	3.3
Paspalum dilatatum Poir.	Poaceae	20	14	3.1
Commelina beghalensis Linn.	Commelinaceae	20	13	3.0
Desmodium racemosum (Thunb.) DC.	Fabaceae	23	12	3.0
Vandelia hirsuta Benth.	Scrophulariaceae	15	13	2.7
Panicum humidorum Hook. f.	Poaceae	16	9	2.2
Artemisia vulgaris non. Linn.	Asteraceae	16	4	1.7
Digitaria longiflora Reitz.	Poaceae	12	7	1.6
Potentilla fulgens Wall.	Rubiaceae	11	7	1.5
Senecio cappa Buch.-Ham.ex D. Don.	Asteraceae	13	4	1.5
Gleichenia sp.	Glecheniaceae	12	4	1.4
Sonerila khasiana Clarke	Melastomataceae	9	6	1.3
Vernonia scandens DC.	Asteraceae	7	6	1.1
Smythea ciliata Wall.	Fabaceae	8	4	1.1
Vitis discolor (Bl) Dalz.	Vitaceae	7	5	1.0
Pteris sp.	Pteridaceae	7	4	0.9
Smythea macrocarpa Hemsl.	Fabaceae	7	2	0.7
Oxalis corniculata Linn.	Oxallidaceae	5	3	0.7
Smilax ferox Kunth.	Smilacaceae	5	3	0.7
Molineria capitulata (Lour.)	Hypoxidaceae	4	3	0.6
Sonchus oleraceus Linn.	Asteraceae	6	2	0.6
Panicum khasianum Munro. ex Hooker	Poaceae	5	2	0.6
Polygonum chinense Linn.	Polygonaceae	5	2	0.6

Rhynchotechum vestitum Wall. ex Cl.	Gesneriacaeae	5	2	0.6
Scutellaria discolor Colebr.	Lamiaceae	3	3	0.6
Sellaginella sp.	Selaginellaceae	5	2	0.6
Paederia foetida auct.	Rubiaceae	4	2	0.5
Senecio scandens Buch.-Ham.exD. Don.	Asteraceae	4	2	0.5
Plantago major (non Linn.) Hook.f.	Plantaginaceae	3	2	0.5
Rubus mollucanus Hk. f.	Rosaceae	3	2	0.5
Stephania japonica (Thunb.) Miers.	Menispermaceae	3	2	0.5
Anaphalis griffithii Hk. f.	Asteraceae	2	2	0.3
Ranunculus cantonensis DC.	Ranunculaceae	2	1	0.2
Scirpus juncoides Roxb.	Cyperaceae	2	1	0.2
Rubus khasianus Cordot.	Rosaceae	1	1	0.2
		1354		**200**

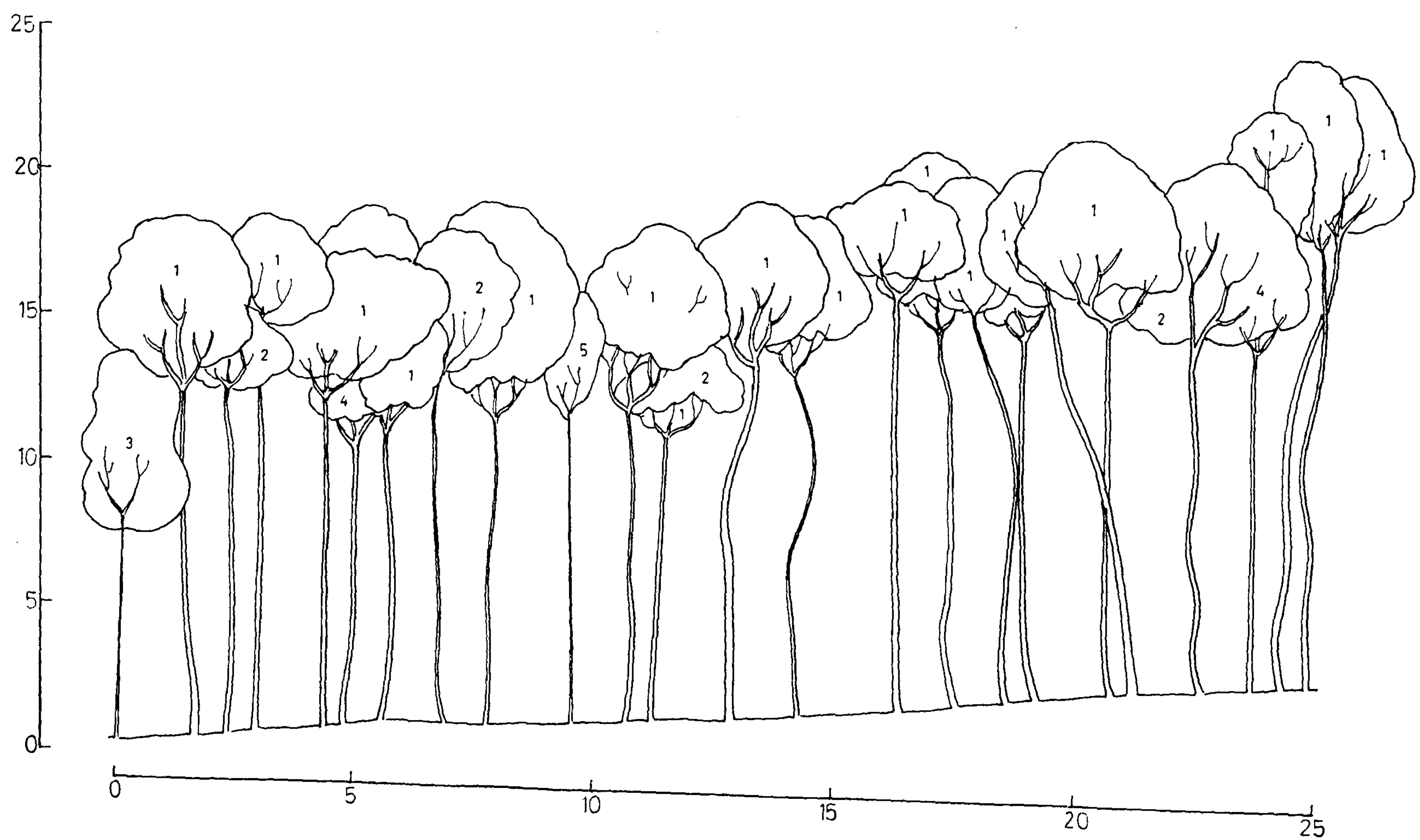


Fig. 7.1. Profile diagram of a subtropical pine (P-I) forest. The diagram represents a strip of forest (25 m long and 5 m wide). 1. *Pinus kesiya*. 2. *Callicarpa arborea*, 3. *Litsea salicifolia*, 4. *Quercus glauca*.

Fig. 7.2. Profile diagram of a subtropical pine (P-II) forest. The diagram represents a strip of forest (25 m long and 5 m wide). 1. *Pinus kesiya*, 2. *Schima wallichii*, 3. *Quercus semiserrata*, 4. *Rhus accuminata*.

roxburghiana and *Schima walichii.* Sub-canopy (10-20 m height) layer is composed of *Rhus javanica*, *Litsea salicifolia*, *Grewia multiflora* and *Engelhardtia spicata,* while treelet layer (2-10 m height) is formed of *Quercus glauca*, *Eurya acuminata* and *Pyrus pashia* (Fig. 7.3). There was no marked differentiation between the sub-canopy and treelet layer of the stand. They together constituted about 78% to 88% of the tree species richness in all the three forests.

Life form

Biological spectra of the stands showed that there was the low dominance of phanerophytes (28% to 39%) than the Raunkiaer's normal (46%). The percentage of therophytes (25% to 38%) and chamaephytes (12% to 15%) in the pine forests was greater than in the Raunkiaer's normal spectrum. The lower percentage of phanerophytes and markedly higher proportion of therophytes in all the pine forest stands as compared to Raunkiaer's normal spectrum indicated relatively unfavourable condition for the growth of phanerophytes in these forests (Fig. 7.4).

Frequency

Majority (56% to 89%) of species showed low frequency in all three forest stands while classes B, C and D, were absent from the stand P-I, and class D from stand P-II and P-III. All other classes were represented by 4% to 22% species in the stands (Fig. 7.5). *Pinus kesiya* and *Schima wallichii* in stand P-I, *P. kesiya* and *Quercus glauca* in stand P-II, and *P. kesiya, Rhododendron*

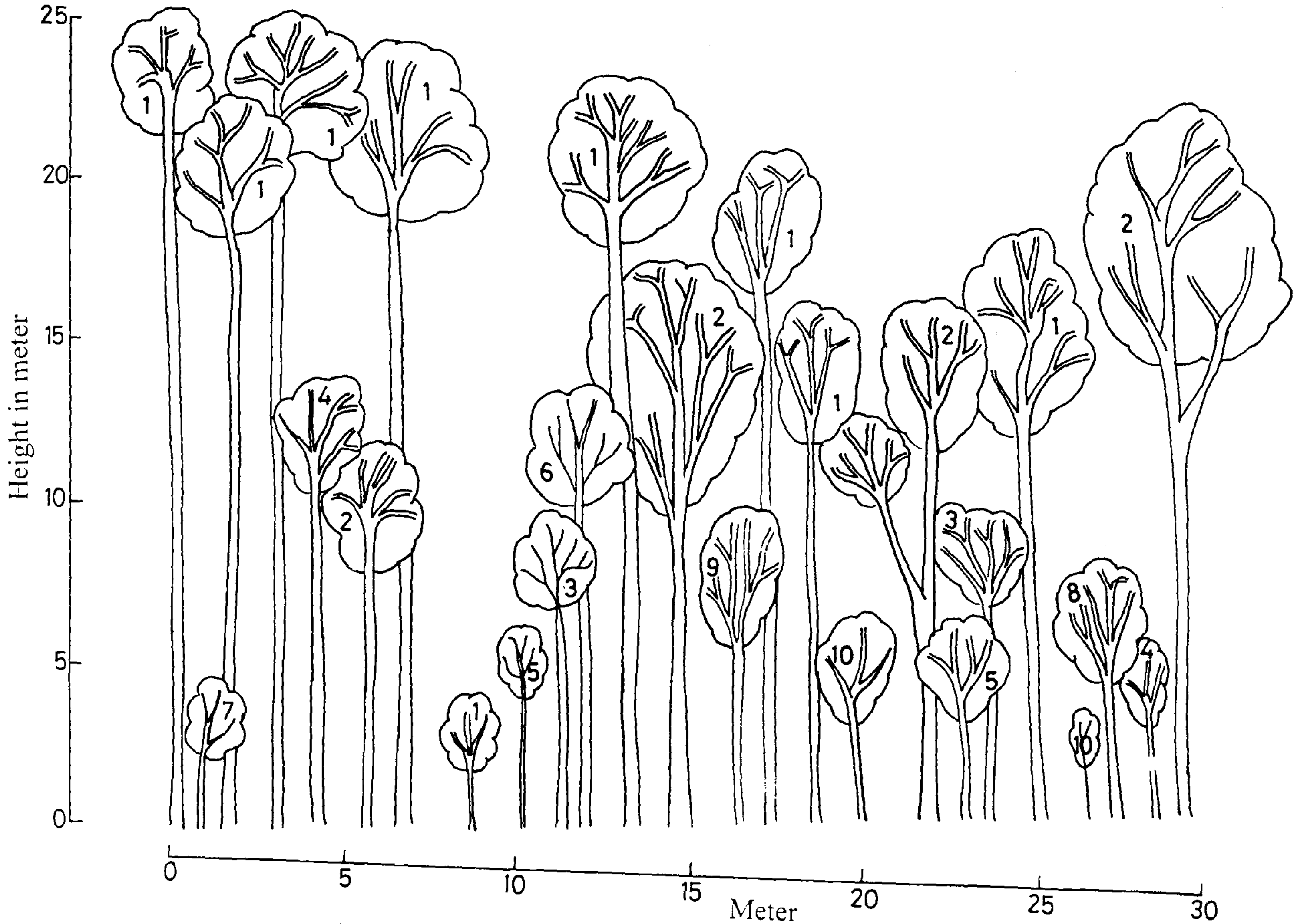


Fig. 7.3. Profile diagram of a subtropical pine (P-III) forest. The diagram represents a strip of forest (30 m long and 5 m wide). 1. *Pinus kesiya*, 2. *Rhododendron arboreum*, 3. *Pyrus pashia*, 4. *Myrica esculenta*, 5. *Alnus nepalensis*, 6. *Exbucklandia populnea*, 7. *Quercus glauca*, 8. *Quercus griffithii*, 9. *Glochidion assamicum*, 10. *Lyonia ovalifolia*.

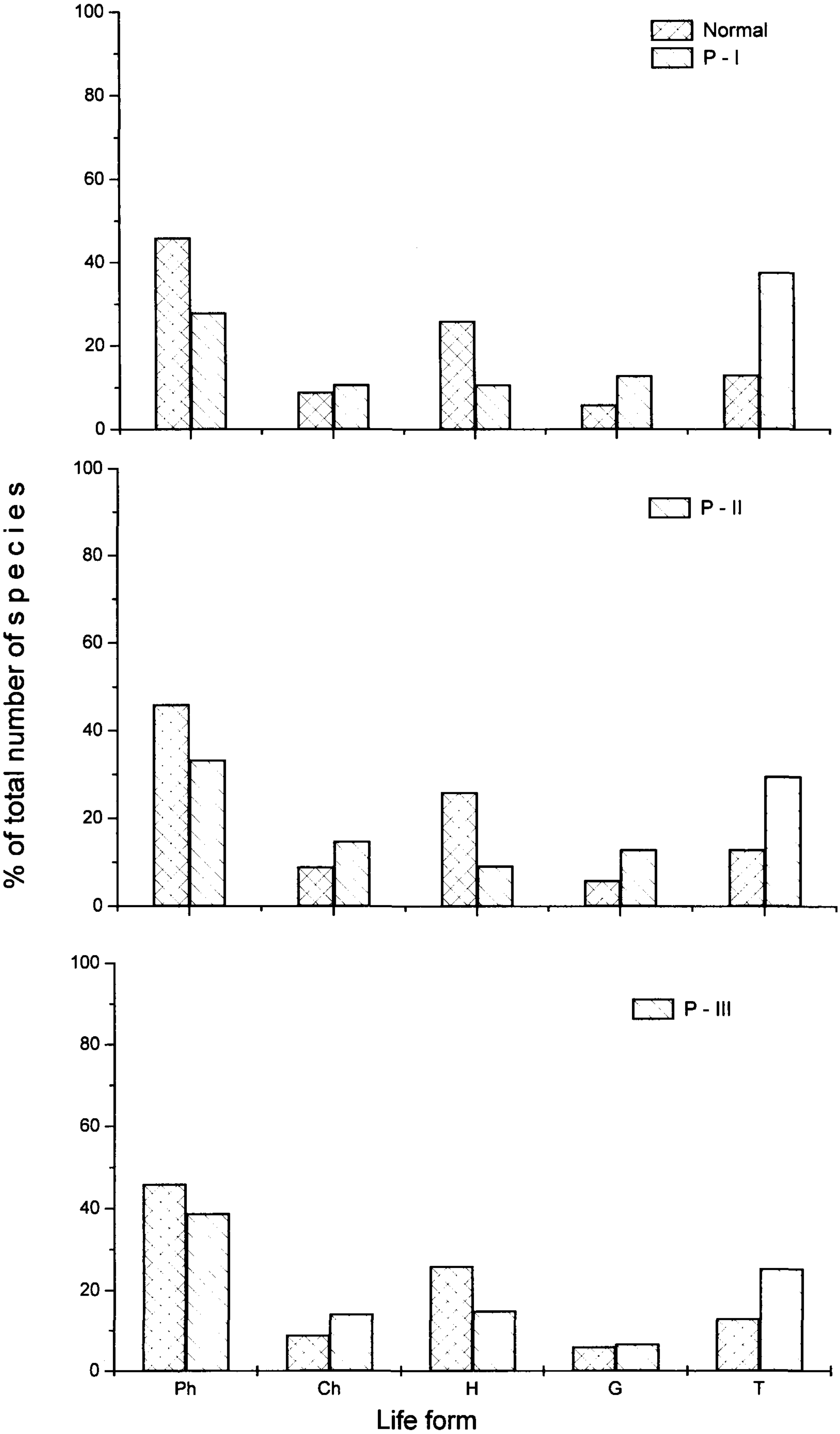


Fig. 7.4. Life form specrta of three stands of the pine forest (Ph - Phanerophytes, Ch - Chamaephytes, H - Hemicryptophytes, G - Geophytes, T - Therophytes).

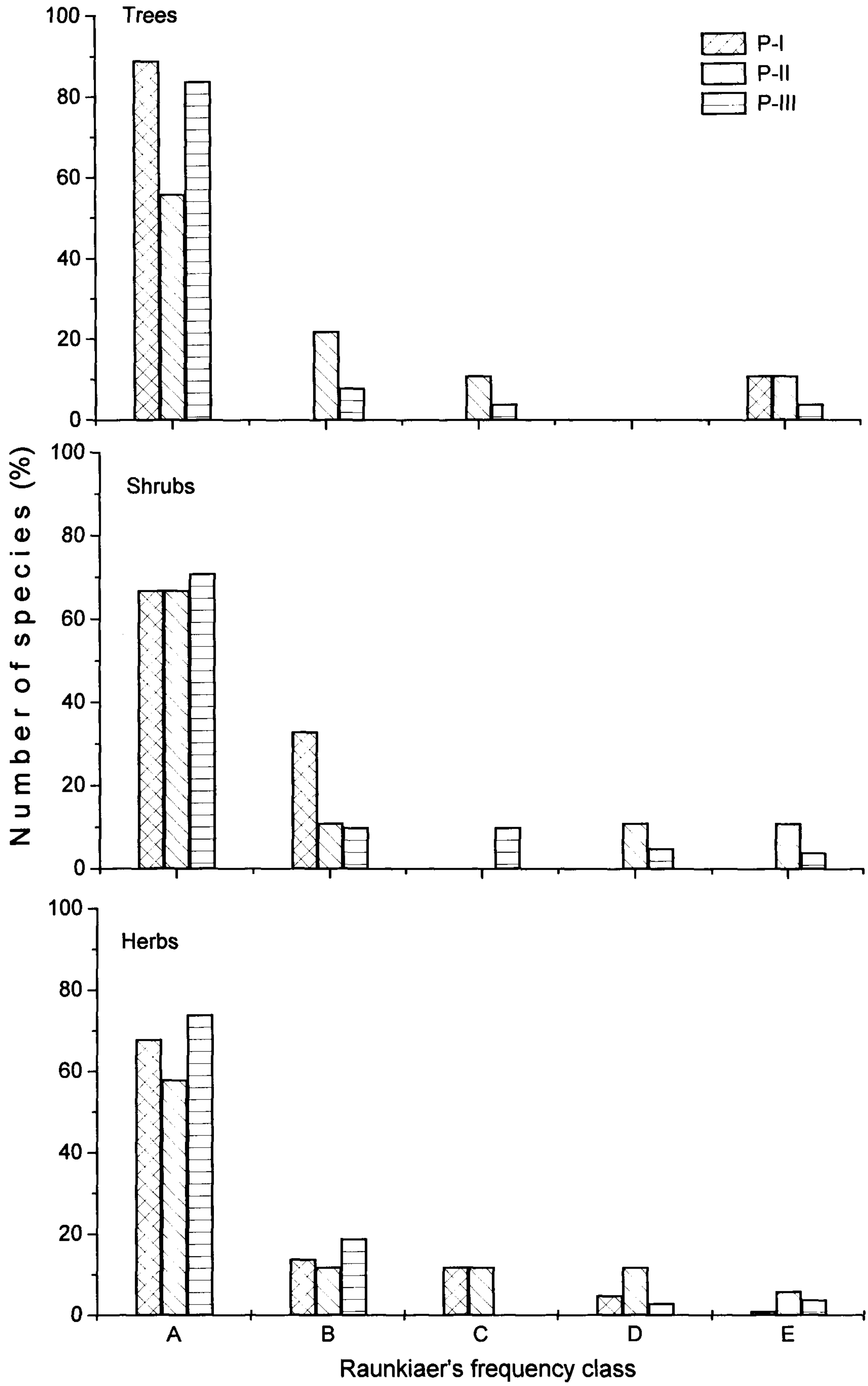


Fig. 7.5. Distribution of plant species in different frequency classes in three (P-I, P-II, P-III) stands of the pine forest

arboreum and *Myrica esculenta* in stand P-III were among the most frequently found tree species in the pine forest community.

Among the shrubs 67-71% species had low (<20%) frequency in all the three stands. In P-I, Raunkiaer's classes C, D and E were absent, while class C was absent in stand P-II (Fig. 7.5). In these three stands, *Eupatorium adenophorum*, *Osbeckia crinata*, *O. chinensis*, *Rubus lasiocarpus*, *Thysanolaena agrostis*, *Melastoma malabathricum* and *Phoenix humilis* were most frequent species (Table 7.1b, 7.2b, 7.3b). About 58-74% of the herbaceous species had <20% frequency in the three forest stands (Fig. 7.5). *Rubia cordifolia*, *Desmodium racemosum*, *Eleusine corocana*, *Pouzolzia latifolia*, *Potentila fulgens*, *Imperata cylindrica*, *Panax pseudoginseng* and *Anaphalis griffithii*, and ferns like *Asplenium* sp. and *Davaellia* sp. had high frequency values (Table 7.1c, 7.2c, 7.3c).

Stand Density and basal cover

The density of tree species (>15 cm cbh) was 1000 ±29, 810 ±34 and 1050 ±21 stems ha^{-1} in stands P-I, P-II and P-III, respectively. Their maximum (37.4 ±2.98 m^2 ha^{-1}) basal cover was recorded in stand P-III, followed by stand P-II (33.1 ±1.56 m^2 ha^{-1}) and stand P-I (28.9 ±2.98 m^2 ha^{-1}) (Table 7.4). *P. kesiya* contributed about 85, 69 and 47 per cent to the total stem density in stands P-I, P-II and P-III, respectively, while the other species were represented by a few individuals only.

Table 7.4. Mean stand density (individuals ha^{-1}) and mean basal cover ($m^2 ha^{-1}$) of tree species in the pine forest.

	Pine forest stands		
	P-I	P-II	P-III
Stand density	1000 ±29	810 ±34	1050 ±21
Basal cover	28.9 ±2.98	33.1 ±1.56	37.4 ±2.98

Based on density contribution, *P. kesiya* (850 stem ha^{-1}) and *Schima wallichii* (40 stem ha^{-1}) in stand P-I, *P. kesiya* (557 stem ha^{-1}), *S. wallichii* (93 stem ha^{-1}) and *Quercus semiserrata* (57 stem ha^{-1}) in stand P-II, and *P. kesiya* (497 stem ha^{-1}), *Rhododendron arboreum* (113 stem ha^{-1}) and *Myrica esulenta* (50 stem ha^{-1}) in stand P-III, were among the dominant tree species in the community (Table 7.1a, 7.2a, 7.3a). In all stands trees having > 55 cm cbh constituted 60%-85% of the tree population, while the proportion of intermediate girth class (35-55 cm cbh) trees ranged between 14 % to 38% and there was no stem in 15-35 cm cbh class except in stand P-III (Fig. 7.6). Basal cover distribution of the stands revealed that higher girth class (>75 cm cbh) trees contributed more towards basal cover in stand P-II and III while in stand P-I, intermediate girth class (35-75 cm cbh) contributed more to the basal cover. There was no individuals having more than 75 cm cbh (Fig. 7.7).

Dominance

In terms of importance value, *P. kesiya* (IVI: 215.3), was the dominant species followed by *Schima wallichii* (IVI: 23.3), *Quercus glauca* (IVI: 13) and *Callicarpa arborea* (IVI: 13) in stand P-I. *P. kesiya* (IVI: 188.8), *Schima wallichii*

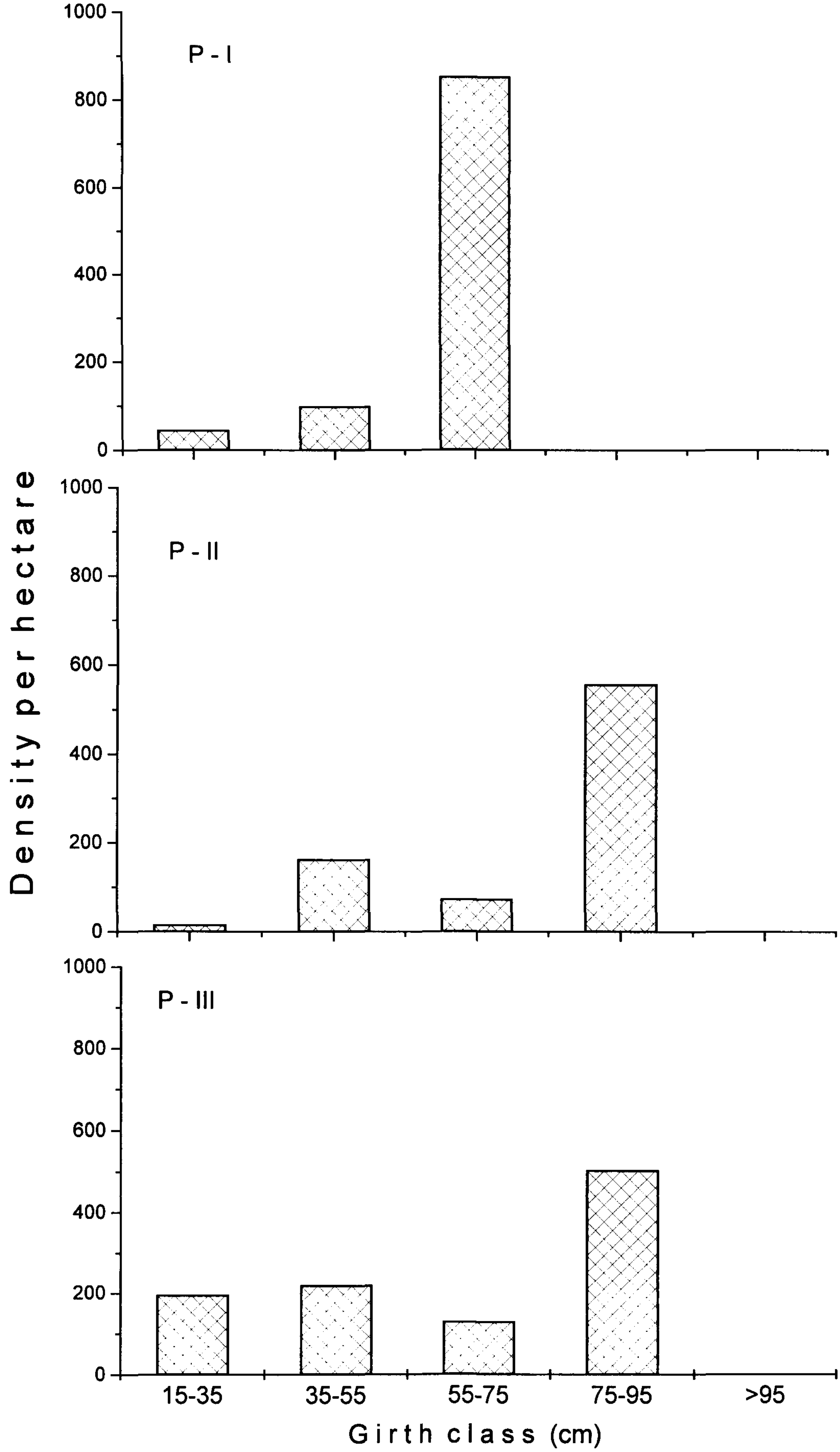


Fig. 7.6. Girth class distribution of tree species in three (P-I, P-II, P-III) stands of the pine forest.

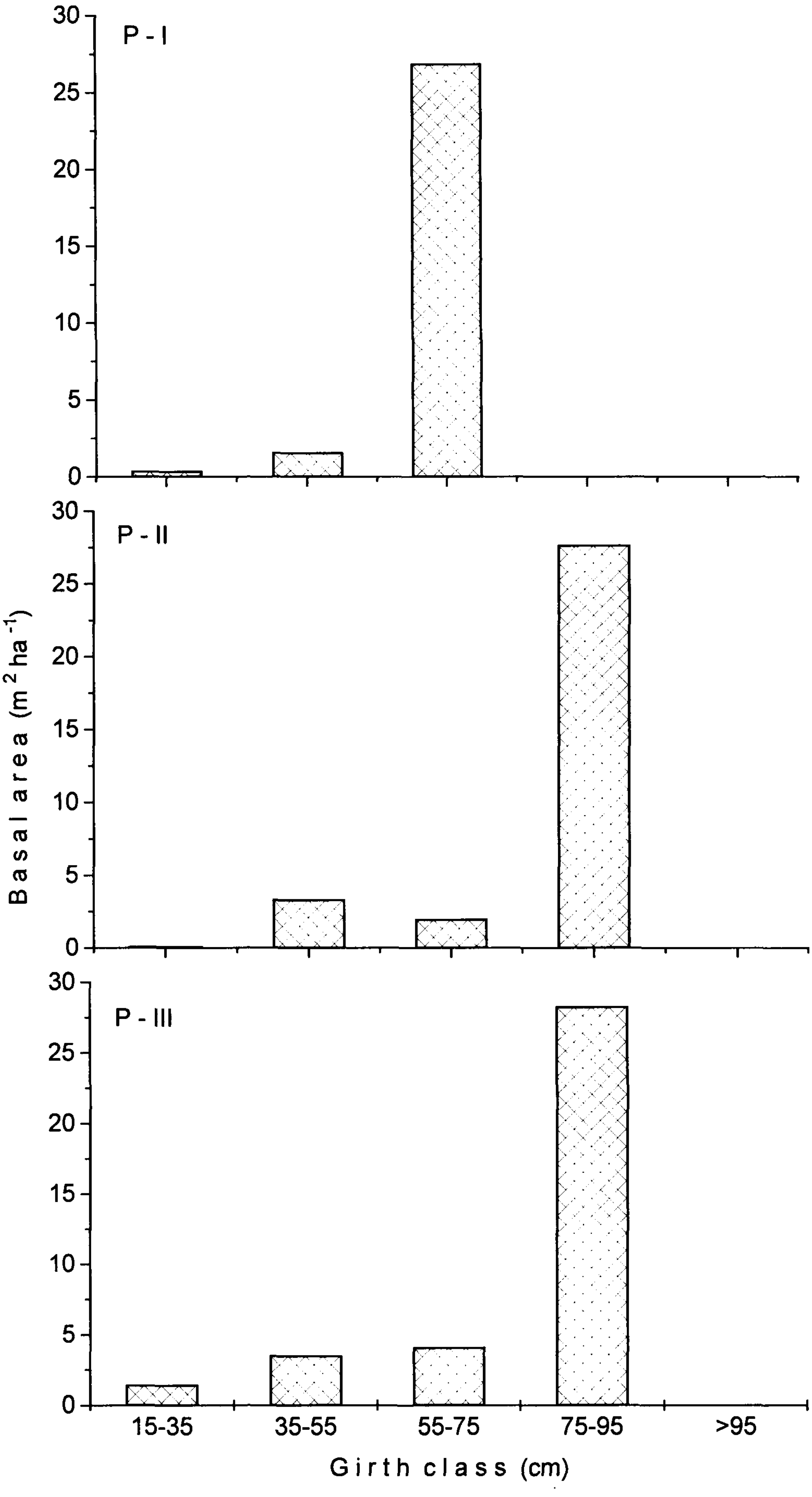


Fig. 7.7. Distribution of tree basal cover in different girth classes in three (P-I, P-II, P-III) stands of the pine forest.

(IVI: 33.4), *Quercus semiserrata* (IVI: 29.4) and *Myrica esculenta* (IVI: 19.7) were dominant in stand P-II, and *P. kesiya* (IVI: 146.7), *Rhododendron arboreum* (IVI: 28.1), *Myrica esculenta* (IVI: 17.6) and *Schima wallichii* (IVI: 7.9) were dominant in stand P-III. *P. kesiya* and *Schima wallichii* were the dominant and co-dominant species in all the three stands. *Quercus semiserrata* and *Rhus acuminata*, and *Lindera latifolia*, *Litsea khasiana*, and *Persea duthiei* were least important tree species in stands P-I, II and III, respectively (Table 7.1a, 7.2a, 7.3a).

In the shrub layer, species like *Phoenix humilis* (IVI: 44.6), *Melastoma malabathricum* (IVI: 36.4), *Lantana camara* (IVI: 29.5) and *Thysaenolaena maxima* (IVI 21.2) in stand P-I, *M. malabathricum* (IVI: 52.5), *Eupatorium adenophorum* (IVI: 50.9) and *L. camara* (IVI: 31.4) in P-II, and *E. adenophorum* (IVI: 43.3), *Osbeckia crinata* (IVI: 37), *Thysaenolaena agrostis* (IVI: 24.5) and *Rubus lasiocarpus* (IVI: 15.8) in stand P-III were among the dominants (Table 7.1b, 7.2b, 7.3b).

Among the herbaceous species *Rubia cordifolia* (IVI: 17.5), *Desmodium racemosum* (IVI: 15.3), *Areca gracilis* (IVI: 14.5), *Asplenium* sp. (IVI: 12.9) and *Eleusine corocana* (IVI: 10.5) were dominant in stand P-I, *Pteris* sp. (IVI: 18.2), *Potentila fulgens* (IVI: 17.8), *Imperata cylindrica* (IVI: 15.2) and *Gleichenia* sp. (IVI: 13.7) in stand P-II, and *Asplenium* sp. (IVI: 18.8), *Davaellia* sp. (IVI: 14.6), *Eriosema chinense* (IVI: 11.8), *Commelina sikkimensis* (IVI: 11) and *Berberis wallichiana* (IVI: 10.6) in stand P-III. *Cyperus pilosus*, *Hoya lanceolata* and *Premna latifolia* in stand P-I, *Rubus rugosus* and *oxalis corniculata* in stand P-II and *Rubus khasianus* in stand P-III were the least important species in the ground layer of the forest (Table 7.1c, 7.2c, 7.3c).

Distribution of dominance among the tree species was dissimilar in the three stands; while it approached geometric series in stands P-I and P-II, it was similar to broken-stick curve in stand P-III(Fig. 7.8).

Similarity and diversity indices

Sorensen's index of similarity between the stands was low and Whittaker 's β-diversity was high. The similarity for tree species was 28.6% to 44.4% while shrubs and herbaceous species showed 23.3% to 48.3% similarity. This revealed that there was a marked difference in species composition between the stands. The above result was also supported by the higher values of Whittaker β-diversity between the stands (Table 7.5).

Table 7.5. Sorensen's index of similarity (%) and Whittaker's β-diversity index for trees (T), shrubs (S) and herbs (H) in the pine forest.

Stands	Similarity index			β-diversity index		
	T	S	H	T	S	H
Stand P I and P II	44.4	31.4	38	0.54	0.53	0.64
Stand P II and P III	28.6	23.3	40	0.71	0.78	0.61
Stand P I and P III	34.3	48.3	41.2	0.66	0.66	0.61

Margalef species richness index for tree species, shrubs and herbs was higher in the stand P-III than the other two stands. Similarly, other diversity indices like Shannon diversity (2.2 to 4.1) and Pielou evenness (0.52 to 0.67) for all three components of the community *i.e.*, trees, shrubs and herbs were

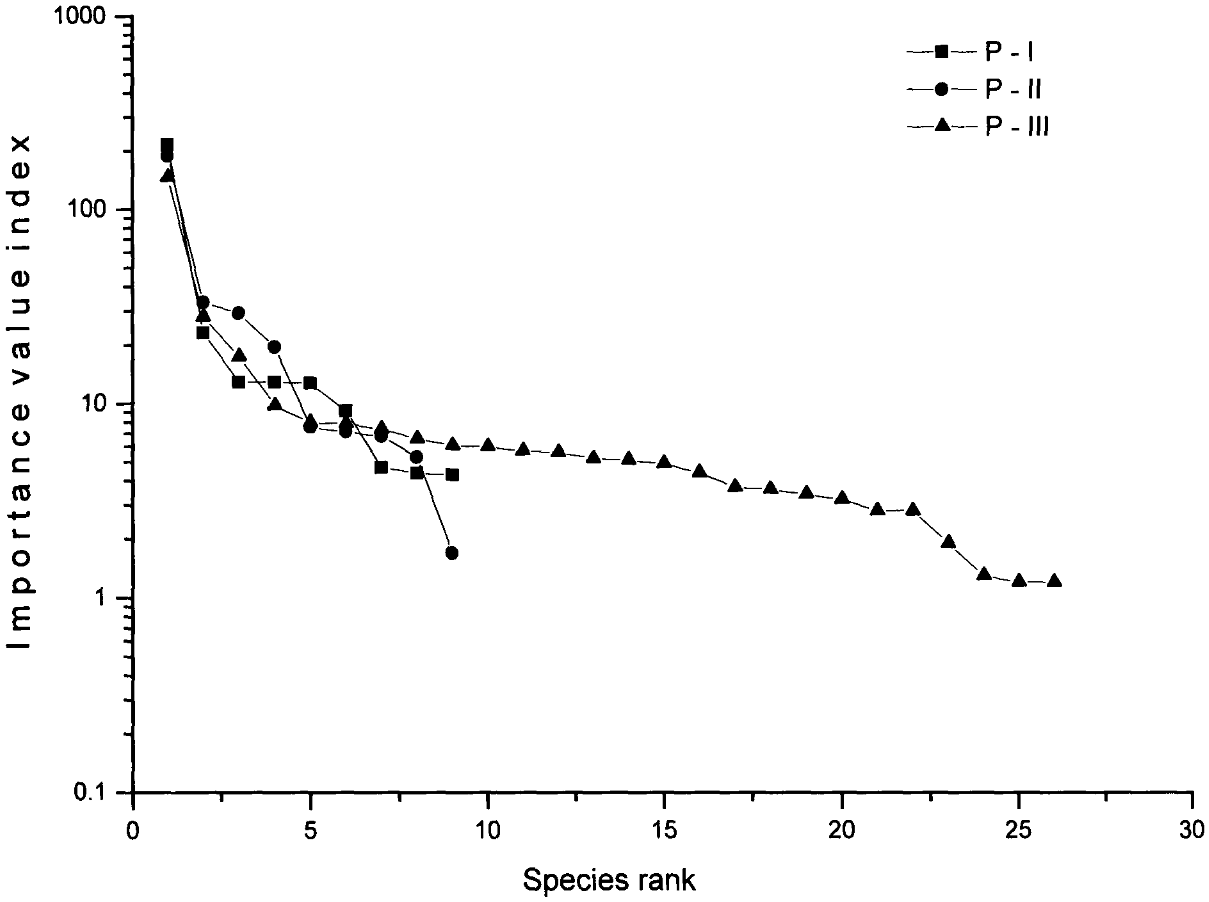


Fig. 7.8. Dominance -diversity curves of tree species (species name are given in Table 7.1a, 7.2a, 7.3a) in three stands of the pine forest.

high in stand P-III. Simpson dominance index was low (0.04 to 0.06) for the herbaceous species in all three stands than the trees and shrubs (Table 7.6).

Table 7.6. Overall community characteristics of the pine forest.

Variables	Stands		
	P-I	P-II	P–III
Trees			
Area sampled (ha)	0.3	0.3	0.3
Density ha^{-1}	1000 ±29	810 ±34	1050 ±21
Basal cover (m^2 ha^{-1})	28.9 ±2.98	33.1 ±1.56	37.4 ±2.98
Species richness	9	9	26
Number of genera	8	8	23
Number of families	8	8	17
Shannon diversity index	1.14	1.31	2.19
Margalef species richness index	1.16	1.2	3.59
Pielou evenness index	0.52	0.6	0.67
Simpson dominance index	0.53	0.43	0.06
Shrubs			
Area sampled (m^2)	750	750	750
Density ha^{-1}	1733 ±59	1883 ±72	1953 ±53
Species richness	12	9	21
Number of genera	11	8	18
Number of families	9	6	14
Shannon diversity index	2.2	1.78	2.39
Margalef species richness index	2.26	1.62	4.21
Pielou evenness index	0.89	0.81	0.79
Simpson dominance index	0.13	0.19	0.12
Herbs			
Area sampled (m^2)	120	120	120
Density per 100 m^2	1669 ±83	1490 ±39	1354 ±67
Species richness	59	26	57
Number of genera	47	25	49
Number of families	30	17	28
Shannon diversity index	3.41	2.95	3.53
Margalef species richness index	7.82	3.42	7.77
Pielou evenness index	0.84	0.91	0.89
Simpson dominance index	0.04	0.06	0.04

Population structure and regeneration of tree species

Density of tree seedling

Mean seedling density (plants per 100 m^2) was 343 ±11, 372 ±33 and 501 ±17 in stands P-I, II and III, respectively. Seedlings of *Quercus glauca*, *Dimocarpus longan*, *Myrica esculenta* and *Albizia chinensis* in stand P-I, *A. chinensis*, *Pinus kesiya*, *Symplocos spicata*, *Rhus javanica* and *Pyrus pashia* in stand P-II, and *Eurya acuminata*, *Combretum acuminatum*, *Lyonia ovalifolia* and *Zanthoxylum alatum* in stand P-III were the common. The species like *Premna latifolia* and *P. racemosa* in stand P-I, *Rhus javanica* in stand P-II, *Daphne cannabina*, *Litsea salicifolia* and *Psychotria adenophylla* in stand P-III had low seedling density (Table 7.7a, 7.7b, 7.7c).

Density of tree sapling

The mean sapling (5-15 cm cbh) density (ha^{-1}) was 1760 ±90, 1787 ±87 and 2212 ±37 in stands P-I, II and III, respectively. The saplings of *Schima wallichii*, *Quercus serrata, Callicarpa arborea* and *Myrica esculenta* were common in stand P-I, those of *Litsea cubeba*, *Quercus glauca*, *Schima wallichii* and *Quercus semiserrata* were common in stand P-II, and saplings of *Myrica esculenta*, *Quercus glauca*, *Lindera leata* and *Litsea citrata* were common in stand P-III. *A. chinensis*, and *Viburnum odoratissimum*, *Callicarpa arborea*, *Glochidion acuminatum* and *Rhus javanica* and *Randia longiflora*, *R. acuminata* and *Olea dioca* in stand P-I, II and III, respectively had low sapling density (Table 7.8a, 7.8b, 7.8c).

Table 7.7a. Density (individual per 100 m²), frequency (%) and importance value index of tree seedlings in stand I of the pine forest.

Name of species	Family	Density	Frequency	IVI
Quercus glauca Thunb.	Fagaceae	112	29	58.8
Dimocarpus longan Lour.	Sapindaceae	76	22	41.5
Myrica esculenta Buch.-Ham.ex D.Don	Myricaceae	27	11	17.6
Albizia chinensis (Osb.) Merr.	Mimosaceae	22	12	16.9
Psychotria adenophylla Wall.	Rubiaceae	22	8	13.9
Quercus serrata Thunb.	Fagaceae	24	8	13.7
Rhus javanica Linn.	Meliaceae	12	8	10.2
Erythroxylum kunthianum Wall. ex Kurz.	Erythroxylaceae	5	4	5.2
Pinus kesiya Royle.ex Gordon.	Pinaceae	11	2	4.7
Premna barbata Wall. ex Sch.	Verbenaceae	11	2	4.7
Syzygium cuminii (Linn) Skeels	Myrtaceae	5	2	2.9
Viburnum foetidum Wall.	Caprifoliaceae	5	2	2.9
Leucosceptrum canum Sm.	Lamiaceae	7	1	2.8
Premna latifolia Roxb.	Verbenaceae	2	2	2.1
Premna racemosa Wall. ex Sch.	Verbenaceae	2	2	2.1
		343		**200**

Table 7.7b. Density (individual per 100 m²), frequency (%) and importance value index of tree seedlings in stand II of the pine forest.

Name of species	Family	Density	Frequency	IVI
Albizia chinensis (Osb.) Merr.	Mimosaceae	216	48	103.0
Pinus kesiya Royle Ex Gordon.	Pinaceae	22	43	49.6
Symplocos spicata Roxb.	Symplocaceae	14	11	13.8
Rhus javanica (non Linn.) Gamble.	Meliaceae	12	12	11.7
Pyrus pashia D.Don	Rosaceae	16	6	5.2
Quercus glauca Thunb.	Fagaceae	28	4	4.7
Litsea salicifolia (Roxb.ex Nees.) Hk.f.	Lauraceae	22	4	4.3
Maesa indica (Roxb.) Wall.	Myrsinaceae	28	3	4.0
Schima wallichii (DC.) Korth.	Theaceae	14	4	3.9
		372		**200**

Table 7.7c. Density (individual 100 m^2), frequency (%) and importance value index of tree seedlings in stand III of the pine forest.

Name of species	Family	Density	Frequency	IVI
Eurya acuminata DC.	Theaceae	68	36	35.8
Lyonia ovalifolia (Wall.) Drude	Ericaceae	47	33	28.2
Zanthoxylum alatum Roxb.	Rutaceae	32	19	18.7
Combretum acuminatum Roxb.	Combretaceae	62	11	14.8
Lindera latifolia Hk.f.	Lauraceae	21	19	12.6
Schima wallichii (DC.) Korth.	Theaceae	23	15	12.1
Eurya japonica Thunb.	Theaceae	71	12	11.8
Pinus kesiya Royle Ex Gordon.	Pinaceae	32	11	10.6
Alnus nepalensis D. Don.	Betulaceae	12	12	8.5
Olax acuminata Benth.	Olaceae	9	12	7.3
Drymaria cordata (Linn) Roem. & Schutt.	Polypodiaceae	7	5	5.9
Maesa indica (Roxb.) Wall.	Myrsinaceae	13	6	5.0
Dimocarpus longan Lour.	Sapindaceae	9	4	4.0
Symplocos spicata Roxb.	Symplocaceae	12	3	3.9
Viburnum odoratissimum Ker.	Caprifoliaceae	17	5	3.8
Syzygium cuminii (Linn) Skeels	Myrtaceae	13	6	3.8
Rhus acuminata DC.	Meliaceae	11	5	3.2
Lindera caudata Benth.	Lauraceae	11	4	2.9
Rhododendron arboreum Sm.	Ericaceae	17	3	2.7
Daphne cannabina Wall.	Thymalaceae	7	3	1.8
Litsea salicifolia (Roxb.ex Nees) Hk. f.	Lauraceae	5	3	1.6
Psychotria adenophylla Wall.	Rubiaceae	2	2	0.9
		501		**200**

Table 7.8a. Density (individual ha^{-1}), frequency (%) and importance value index of tree saplings in stand I of the pine forest.

Name of species	Family	Density	Frequency	IVI
Schima wallichii (DC.) Korth.	Theaceae	467	40	50.0
Quercus serrata Thunb.	Fagaceae	347	30	37.3
Callicarpa arborea Roxb.	Verbenaceae	187	17	20.4
Myrica esculenta Buch.-Ham.ex D. Don	Myricaceae	160	17	18.9
Lagerstroemia parviflora Roxb.	Lythraceae	147	17	18.1
Rhus javanica Linn.	Anacardiaceae	120	13	14.7
Acacia pinnata (Linn.) Wild.	Caesalpiniaceae	147	10	14.2
Quercus glauca Thunb.	Fagaceae	80	13	12.4
Albizia chinensis (Osb.) Merr.	Mimosaceae	53	7	7.0
Viburnum odoratissimum Ker.	Caprifoliaceae	53	7	7.0
		1760		**200**

Table 7.8b. Density (individual ha^{-1}), frequency (%) and importance value index of tree saplings in stand II of the pine forest.

Name of species	Family	Density	Frequency	IVI
Litsea cubeba Lour.	Lauraceae	573	70	60.9
Quercus glauca Thunb.	Fagaceae	333	57	42.0
Schima wallichii (DC.) Korth.	Theaceae	293	43	34.2
Quercus semiserrata Roxb.	Fagaceae	160	17	15.8
Eurya acuminata DC.	Theaceae	120	10	10.8
Myrica esculenta Buch.-Ham.ex D. Don	Myricaceae	93	13	10.7
Pyrus pashia D.Don	Rosaceae	53	10	7.1
Albizia chinensis (Osb.) Merr.	Mimosaceae	67	7	6.5
Callicarpa arborea Roxb.	Verbenaceae	40	7	5.0
Glochidion acuminatum Muell.-Arg.	Euphorbiaceae	27	7	4.2
Rhus javanica (non Linn.) Kanjilal	Anacardiaceae	27	3	2.9
		1787		**200**

Table 7.8c. Density (individual ha^{-1}), frequency (%) and importance value index of tree saplings in stand III of the pine forest.

Name of species	Family	Density	Frequency	IVI
Myrica esculenta Buch.-Ham.ex D. Don.	Myricaceae	212	27	19.8
Quercus glauca Thunb.	Fagaceae	176	20	15.7
Lindera laeta Wall.ex Nees.	Lauraceae	153	17	13.3
Litsea citrata Bl.	Lauraceae	141	17	12.8
Lyonia ovalifolia (Wall.) Druce.	Ericaceae	141	17	12.8
Alnus nepalensis D. Don	Betulaceae	129	10	9.7
Glochidion lanceolarium (Roxb.) Voigt.	Euphorbiaceae	94	13	9.4
Lindera caudata Benth.	Lauraceae	118	10	9.2
Erythrina stricta Roxb.	Leguminosae	94	10	8.1
Rhododendron arboreum Sm.	Ericaceae	106	7	7.4
Eurya acuminata DC.	Theaceae	71	10	7.0
Persea duthiei King.ex Hk.f.	Lauraceae	59	10	6.5
Prunus cerasoides D. Don.	Rosaceae	59	10	6.5
Quercus griffithii Hk.f. & Th.ex DC.	Fagaceae	59	10	6.5
Rhus javanica Linn.	Anacardiaceae	59	10	6.5
Cinnamomum glanduliferum (Wall.) Meissn.	Lauraceae	71	7	5.8
Litsea salicifolia (Roxb.ex Nees.) Hk.f.	Lauraceae	71	7	5.8
Engelhardtia spicata Leschn ex Bl.	Juglandaceae	59	7	5.2
Quercus serrata Thunb.	Fagaceae	59	7	5.2
Exbucklandia populnea (R.Br.ex Griff.) R.W.Br.	Hamamelidacea e	47	7	4.7
Beilshmiedia brandisii Hk.f.	Lauraceae	59	3	3.9
Prunus undulata Steud.	Rosaceae	24	7	3.6
Eurya japonica Thunb.	Theaceae	35	3	2.9
Schima wallichii (DC.) Korth.	Theaceae	35	3	2.9
Persea bombycina King.ex Hk.f.	Lauraceae	24	3	2.3
Randia longiflora Lamk.	Rubiaceae	24	3	2.3
Rhus acuminata Linn.	Anacardiaceae	24	3	2.3
Olea dioica Roxb.	Oleaceae	12	3	1.8
		2212		**200**

Density of adult trees

The mean density of adult (>15 cm cbh) trees was 1000 ±29, 810 ±34 and 1050 ±21 stem ha^{-1} in stands P-I, II and III, respectively (Table 7.4).

The overall population density of seedlings, saplings and adult trees of all the three stands revealed that there was preponderance of tree seedlings and substantially low population density of saplings and adult trees especially in case of stand P-III. Based on this observation, the population of seedlings may be considered as the most vulnerable in the life cycle of these trees (Fig. 7.9).

In all the three stands the states of regeneration of *Pinus kesiya* was assessed based on the relative size of the populations of seedlings, saplings and adult trees. Regeneration of pine was better in stand P-I, where individuals of all ages from seedling to mature tree were present. In the other two stands the regeneration of pine was impeded as was indicated by the absence of either seedlings or saplings (Fig. 7.10).

Discussion

The *Pinus kesiya* forests at the higher reaches of Shillong plateau in the state of Meghalaya have developed following the destruction of semi evergreen montane forest primarily by shifting cultivation and annual burning during the dry winter season. These are fairly stable plant communities under anthropogenic stresses such as lopping, grazing and surface fire and represent the biotic climax of the area. The population structure of tree species and their regeneration and dominance as well as species diversity are, therefore, strongly influenced by these forces in the pine forest ecosystem.

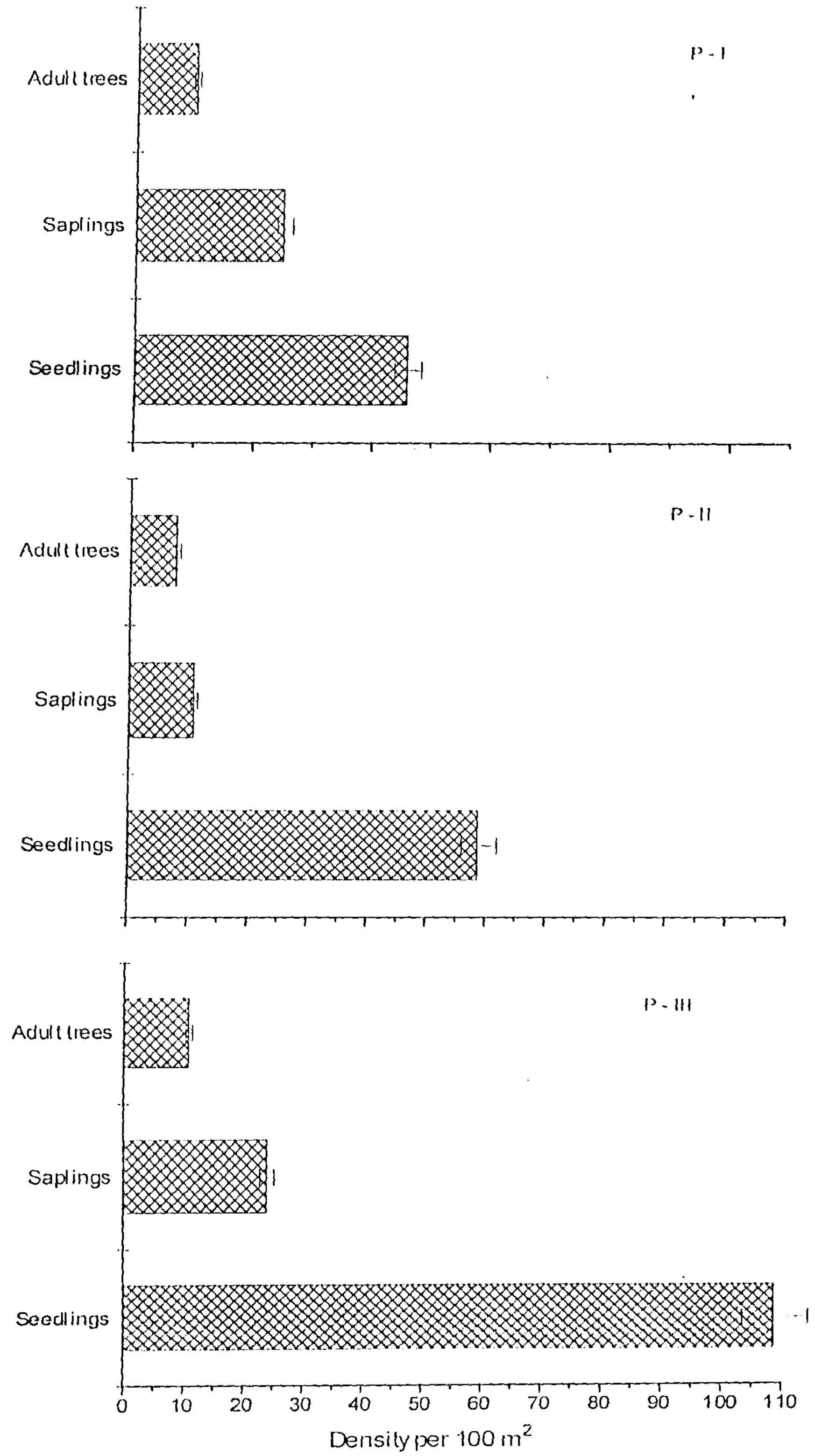


Fig.7.9. Population density of seedlings, saplings and adult trees in the three stands of pine forest.

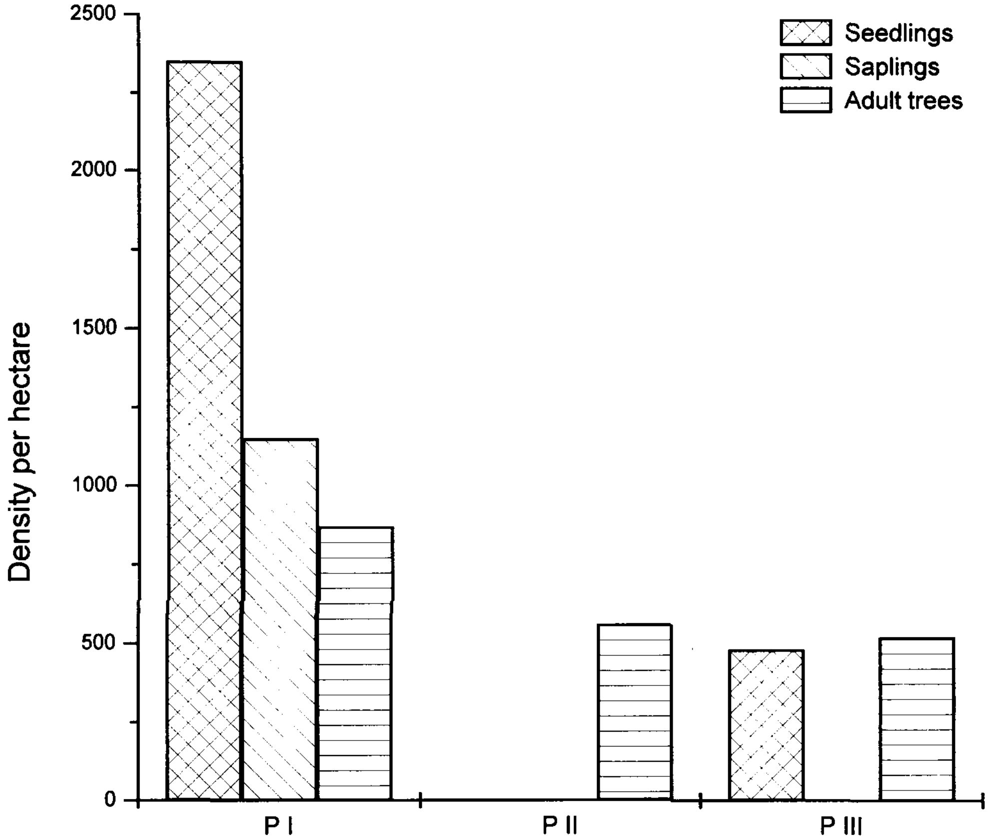


Fig. 7.10. Density of pine seedlings, saplings and adult trees in the three stands of subtropical pine forest.

The species composition in the three pine stands differed markedly both in qualitative and quantitative terms. Despite general similarity in the soil condition at the three stands, there was a marked variation in species content between the stands which could be related to the age of the stands and the degree of disturbance to which they are exposed. Another factor that seems to have influenced the community characteristics, particularly in stand P-III, is the relatively moist and cool climate at this site. As a result, the stand P-III, which was relatively less disturbed and was older in age (as is evident by the preponderance of trees of higher (>55cm cbh) girth classes, had highest species richness as compared to the relatively young and more disturbed stands P-I and P-II located at the lower altitude.

The forest canopy in all the three stands was composed mainly of *P. kesiya*. However, a few broad-leaved trees such as *Schima wallichii, Exbucklandia populnea, Lyonia ovalifolia* were also present in the canopy of different stands. The under-canopy layer composed of small trees of *Quercus griffithii* and *Q. glauca* and shrubs like *Grewia multiflora*, *Neillia thyrsiflora* and *Rubus ellipticus* was distinct only in stand P-III. A steep rise in species richness of tree elements as well as herbaceous species from young stands (P-I and P-II) to old stand (P-III) could be attributed to the successional process (Nicholson and Monk 1974, Peet and Christensen 1980). Higher values for species richness, diversity and evenness indices in the old stand (P-III) as compared to the younger stands (P-I and P-II), support the hypothesis that during succession the species diversity increases in the community (Elton 1958).

Jamir (2000) has reported 223 to 334 plant species from 0.35 ha area and Upadhaya *et al.* (2002) have reported 80-82 tree species from 0.5 ha area of the protected subtropical semi-evergreen forests of Jaintia hills in Meghalaya. Compared to these values, 0.3 ha area of the pine forest had 54 -134 plant (including tree seedlings and saplings) species including 9-26 tree species. Based on these values, it may be concluded that the conversion of subtropical evergreen forest into subtropical pine forest resulted into a 2.5 to 4.0 fold decrease in plant species richness and 3 to 9 fold decrease in the tree species richness in the community.

Life form spectrum of the subtropical pine forests presented in Fig. 7.4 showed dominance of therophytes followed by phanerophytes, which suggested transformation of mesic habitat supporting broad-leaved forest into disturbed xeric habitats, which provide more favourable condition to annuals and tolerant tree species like *Pinus kesiya*.

The dominance-distribution curves, which signify equitability and stability of the community, gradually changed from steep logarithmic type in stands P-I and P-II to broken stick type in a relatively less disturbed stand P-III, thereby indicating low equitability in distribution of dominance of tree species in the stands of the forest community of old pine stand.

The girth class distribution (diameter-distribution) of tree species has been frequently used to represent the population structure of forests (Khan *et al.* 1987, Saxena *et al.* 1984, Rao *et al.* 1990). Selective thinning of treelets for fuelwood and their death due to annual surface fire seem to be the major causes of absence of young individuals (>35 cm cbh) in stands P-I and P-II. On the contrary, the greater frequency of the lower girth classes in stand P-III could be attributed to the fewer disturbances. The reduction in density from 1050 ±21 stem ha^{-1} of tree species in stand P-III to 810 ± 34 stem ha^{-1} in stand P-II depicts the cumulative effect of natural thinning, selective cutting and surface fire that cause sapling mortality. Competition from mature trees and herbaceous flora for light, space and nutrients could be another cause of mortality of pine seedlings and saplings as reported by Harmer (1995) and Stout and Marion (1993).

Tree regeneration in the forest is largely dependent upon the response of the seedlings and saplings to the forest microenvironment and interactive influence of an array of biotic and abiotic factors. In stand P-I the regeneration of pine may be considered as good, since the populations of seedling was greater than the sapling population and the latter was greater than the population of adult trees (Uma Shankar 2001). But in stand P-II both seedlings and saplings were absent due mainly to annual fire and trampling by the grazing cattle, which indicates that the regeneration of pine was poor in this stand. The keen competition offered to the pine seedlings by the overhead broad-leaved trees for light and by the dense undergrowth for water and nutrients, appears to be the main reason for the absence of shade-intolerant pine saplings in stand P-III which was older in age and contained few broad-leaved tree species in the forest canopy.

CHAPTER VIII

GENERAL DISCUSSION

All three major types of forests *viz.*, subtropical evergreen, semi evergreen and pine forests covering about 41% of the geographical area of the state of Meghalaya are found between 800m and 2000m asl. The climate at these altitudes is strongly seasonal with about 7-8 month-long rainy season alternating with relatively dry period of 4-5 months during a year. Monthly rainfall during the wet period generally exceeds 100mm, with exceptionally high downpour at certain places located in the southern part of the state. Rainy season is the warmer period of the year, during which temperature ranges between 19 ^{0}C and 25 ^{0}C with a maximum of 26.7 ^{0}C in the month of June/July. Temperature starts declining during the post-rainy season dropping to a minimum of 10.3 ^{0}C at higher altitude, where morning frost is common during mid-winter and January.

The forests occurring below 1000 m are either evergreen or semi-evergreen depending on the dominance of evergreen and deciduous trees in the canopy. The evergreen forest is found where rainfall is relatively high and soil moisture condition remains favourable for most part of the year. The areas, where annual rainfall is relatively low and retention of water in soil is low due to coarse texture, or higher slope gradient or both, support semi-evergreen forest. Human intervention in both evergreen and semi-evergreen broad-leaved forests have paved the way for the development of pine forests, which represent edaphic and biotic climax community between 800 and 2000m altitude in the state. Pine forest is a stable secondary community on disturbed sites, which are seasonally dry and nutrient poor.

The soil profile in broad-leaved forest is well developed, acidic and rich in organic matter and nutrients. On the contrary, the upper soil layer in the pine forest is frequently disturbed by grazing and annual fire during dry winter which burns the thin layer of tree litter, seedlings and dried shoots of annual and perennial species. The nutrients present in the ash are washed off during rainy season leaving behind acidic and nutrient-poor soil substrata in the forest.

None of the above forest types is found in the vast continuous stretches, rather all of them are highly fragmented; the size of the patch ranges from ≤1 sq. km to ≥110 sq. km. All forest types in the state are highly disturbed as is clearly evident from the high frequency of small-size forest patches. However, pine forests are most disturbed and very highly fragmented.

Often the evergreen forest changes into semi evergreen or pine forest under the influence of topographic, edaphic and biotic factors. Biotic factor, particularly human interference in the form of shifting agriculture, timber extraction and fuel wood collection, and to a lesser extent, cattle grazing have accelerated the fragmentation process of these forests, except at few places where continuous forest patch exceeds 50 sq. km area. Such places in the state are Nokrek biosphere reserve (Garo hills), Nongkhyllum wild life reserve (Ri bhoi), Saipung and Narpuh reserve (Jaintia hills) forest areas. As of now, no scientific study has been undertaken to evaluate the impact of fragmentation on plant diversity and population dynamics of trees and other species of ecological and economic importance in the state.

Fragmentation of the forest may have serious consequences on species composition, community structure and regeneration of trees in the forest communities of the state. Already there are few reports expressing concern about the adverse effect of tree felling and forest degradation in the state (Tripathi *et al.* 1996, Tiwari *et al.* 1998, Jamir 2000).

The present study, though not directly touching the above aspect, gives an overall view of the status of plant diversity in these forest types and analyses the population behaviour of dominant tree species in each of the above three forest types of the state of Meghalaya.

Plant diversity

The most conspicuous features of the tropical and subtropical humid forests are their species richness, heterogeneity and complex community organisation. These forests together comprise the majority of the species present on the Earth. Rainfall pattern and temperature regimes strongly influence their floristic composition, which is further modified by edaphic and biotic influences (WCMC 1992). Richards (1996) has argued that high species content per unit area is largely due to presence of many synusiae in the forest.

However, one of the central and important questions confronting the community ecologists is to provide a satisfactory explanation as to what determines the species richness in a plant community. Rainfall and temperature are two major climatic variables, which are known to have a strong influence on species richness at global or regional levels (Champion and Seth 1968), while edaphic and biotic factors modify the influence of rainfall and temperature at local level (Puri *et al.* 1983). Besides, the species richness also changes with the age of the community (WCMC 1992, Archibold 1995).

A comparison of species richness in different communities is a difficult exercise and often leads to fallible conclusions. The difficulty arises mainly on account of wide variation in the sampling area studied by different researchers. A comparative account of the area sampled by different workers in tropical humid forests and their results on species richness are presented in Table 8.1. It is evident from the data furnished in Table 8.1 that the species richness of the evergreen and semi evergreen forests reported in the present study, seems to be lower than some of the forests on the one hand, and higher than the others, on the other hand. Thus, on the basis of the available data, it is extremely difficult to give plausible reasons for such a variation in the species richness.

Interestingly, the ground flora in the pine forest was richer in species content than the other two forest types of Meghalaya. This could be attributed to the sparse canopy of the pine forest, that favours colonization of large number of weedy species and grasses in the community. This finding is in agreement with Givnish (1995) who has reported that an open canopy allows more light into the under-storey that may permit abundant growth of herbs and shrubs.

Table 8.1. Tree species richness reported in different tropical and subtropical forests of the world.

Site	Area (ha)	Cbh/dbh	Species	Author (s)
Kurupukari	4	5/dbh	153	Jhonston and Gillman 1995
Uttara Kannada	4	10/cbh	36 - 63	Bhatt *et al.* 2000
Agumbe	3	10/cbh	56 - 71	Srinivas and Parthasarathy, 2000
Puthupet	2	10/cbh	51	Parthasarathy and Sethi 1997
Amazonia Ecuador	1	5/dbh	473	Valencia *et al.* 1994
Thailand	1	5/dbh	76 - 100	Bunyavejchewin 1999
Kuzhanthaikuppam	1	10/cbh	42	Parthasarathy and Karthikeyan 1997
Thirumanikkuzhi	1	10/cbh	38	Parthasarathy and Karthikeyan 1997
Evergreen forest, France	1	10/cbh	40	Strasberg 1996
Jaintia Hills	0.8	5/dbh	135	Jamir 2000
Mt. Kinabalu	0.5	5/dbh	121	Aiba and Kitayama 1999
Xishuangbanna	0.16	5/dbh	48	Cao and Zhang 1997

Family dominance

The dominance of the families Lauraceae, Euphorbiaceae, Moraceae and Rubiaceae in the evergreen and semi evergreen forests of Meghalaya bears a good deal of similarity with Amazonian tropical rain forest and tropical forests of Sierra de Manantlam where Leguminaceae, Lauraceae, Moraceae, Rubiaceae and Euphorbiaceae have been reported to be the dominant families in the community (Gentry 1988, Vazquez and Givnish 1998). The forest in the Western Ghats (Ayyappan 2002) as well as Pasoh reserve forest of Malaysia (Manokaran *et al.* 1991) also have Euphorbiaceae as a dominant family.

Majority of the species was contagiously distributed. This could be attributed to inefficient mode of seed dispersal (Richards 1996). Hubbell and Foster (1983) argued that this type of distribution pattern is also linked with the topography and soils, and is influenced by transient historical factors, such as tree fall, disturbance and site factors. Regular dispersion observed in 1-23% of the species and random distribution pattern in 2% to 33% of them may be the consequence of direct competition for water or allelopathy or frequent disturbance (Armesto *et al.* 1986), which largely contributes to the maintenance of high levels of diversity (Connel 1971).

The distinct vertical stratification observed in evergreen and semi-evergreen broad-leaved forests was not seen in the pine forests, except in stand P-III, which was less disturbed and older in age than the other two pine stands. A marked increase in therophytes in pine forests suggests transformation of mesic habitat into disturbed xeric habitats, which was more congenial to annuals and tolerant tree species like *Pinus kesiya*. Higher values of β-diversity index and low similarity index as observed in the present study, revealed that there is a marked difference between the forests in terms of their species content.

Thus it appears that the disturbance has led to simplification of the community organization, and alteration of niches of the indigenous species in favour of tolerant weedy species, which are abundant in the pine forest. However, the overall species richness as indicated by Margalef species richness index was high (11-15) in the semi-evergreen forest followed by evergreen (10-14) and pine (1-4) forests (Table 8.3). The importance of canopy and sub canopy species in creating varied kinds of favourable niches for an array of species in the humid tropical forests has been emphasized by many workers (Ashton 1995, Richards 1996, Cao and Zhang 1997).

Diversity and dominance indices

In respect of the tree species diversity ($\bar{H}$=3.90-4.17) the evergreen and semi-evergreen forests ($\bar{H}$=4.21-4.25) are comparable to the tropical forest at Xishuangbanna ($\bar{H}$=3.29) (Cao and Zhang 1997), Mount Kinabalu rain forest ($\bar{H}$=4.18) (Aiba and Kitayama 1999) and the subtropical evergreen forests of Jaintia hills, Meghalaya ($\bar{H}$=3.74-4.30) (Jamir 2000).

The change in dominance distribution pattern from lognormal type in the subtropical evergreen and semi-evergreen forests to steep logarithmic type in the two stands of pine forest indicates marked shift from high equitability to high dominance in the community due primarily to disturbance.

The tree density in the evergreen and semi-evergreen forests and their distribution in different girth classes could be related to gap phase dynamics, tree regeneration behaviour and age of the stand. In the pine forest, the tree density and their distribution in the various girt-classes seems to be determined by the cumulative effect of natural thinning, selective cutting and surface fire as these factors cause heavy mortality of tree seedlings and saplings. The tree density in the evergreen (834-1723 stems ha^{-1}), semi-evergreen (838-1063 stems ha^{-1}) and pine (810-1050 stems ha^{-1}) forests of Meghalaya is close (Table 8.2) to the tropical forests found in other parts of India as well as the world

(Pelissier and Riera 1993, Strasberg 1996, Parthasarathy and Karthikeyan 1997, Bunyavezchewin 1999, Jamir 2000 and Upadhaya *et al.* 2002).

Table 8.2. Mean stand density and mean basal cover (m^2 ha^{-1}) of tree species reported in different tropical and subtropical forests of the world.

Site	Area (ha)	Cbh/dbh	Density	Basal cover	Author (s)
Uttara Kannada	4	10/cbh	1619	32.1	Bhatt *et al.* 2000
Agumbe	3	10/cbh	1067-1576	35.4-38.2	Srinivas and Parthasarathy, 2000
French, Guyana	1	5/dbh	1168	37.94	Pelissier and Riera 1993
Amazonia Ecuador	1	5/dbh	1561	29.1	Valencia *et al.* 1994
Thailand	1	5/dbh	1168	29.1	Bunyavejchewin 1999
Kuzhanthaikuppam	1	10/cbh	1367	15.44	Parthasarathy and Karthikeyan 1997
Thirumanikkuzhi	1	10/cbh	974	29.48	Parthasarathy and Karthikeyan 1997
Evergreen forest, France	1	10/cbh	1079	81.46	Strasberg 1996
Jaintia Hills	0.8	5/dbh	1070		Jamir 2000
Mt. Kinabalu	0.5	5/dbh	1730		Aiba and Kitayama 1999

In terms of basal cover too, all the three forest types were similar (Table 8.2) and the values are comparable to those reported by Kadavul and Parthasarathy (1993, 1994) from tropical semi-evergreen forests of the Eastern Ghats (21.6-44.5 m^2 ha^{-1}), by Gentry (1988) from Amazonian tropical rain forest (27.6 to 32.1 m^2 ha^{-1}), by Pascal and Pelisser (1996) from tropical wet evergreen forest, Karnataka (39.7 m^2 ha^{-1}), and by Upadhaya *et al.* (2002) from sacred groves of Jaintia hills, Meghalaya (36-72 m^2 ha^{-1}).

Population structure and regeneration

In undisturbed tropical humid forests tree regeneration is largely dependent upon the response of the seedlings and saplings to the forest microenvironment and interactive influence of an array of biotic and abiotic factors. Presence of a large proportion of young individuals in the populations of most of the tree species suggested better regeneration, while poor density or sometimes-complete absence of seedlings in some stands was the reflection of the unfavourable condition in the stand. The poor regeneration in certain stands of the evergreen forest could be attributed mainly to the dense overhead canopy that causes significant reduction (810 lux or 13% of the outside forest) in the light intensity on the forest floor. The sparse canopy and greater number of deciduous trees in the semi evergreen forest, allow sufficient light (1198-2350 lux) reaching the forest floor which enhances regeneration of light demanding species. It could also be due to presence of favourable micro-sites on the forest floor (Barik *et al.* 1992, Jamir 2000).

Thick layer of litter acts as a mechanical barrier for seedling emergence (Tripathi and Khan 1992). Keen competition offered to the seedlings by the dense undergrowth is another important reason for the absence of shade-intolerant seedlings and saplings in these forests. Tree regeneration in the climax subtropical humid forest of the state has been studied by many earlier workers (Khan *et al.* 1987, Rao *et al.* 1990, Khan and Tripathi 1991) who have reported that human - and livestock - induced disturbances are chief causes of poor regeneration in the forest. The overall tree regeneration in all the three forests may be considered as good, since the populations of seedlings and saplings were larger than that of adult trees (Uma Shankar 2001).

The diameter-distribution of tree species has been frequently used to represent the tree population structure of forests (Khan *et al.* 1987, Rao *et al.* 1990). Out of the ten dominant species in the evergreen forest, 5 species namely, *Castanopsis indica, Engelhardtia spicata, Callicarpa vestita, Beilshmiedia roxburghiana, Ficus elastica* and *Macaranga denticulata* showed good regeneration, 2 species (*Bridelia retusa* and *Saprosma ternatum*) showed poor or nil regeneration and the rest (*Citrus hystrix* and *Castanopsis tribuloides*) showed fair regeneration. In the subtropical semi-evergreen forest nine species (including *Eurya japonica* and *Schima wallichii*) did not show any regeneration, while *Helicia nilagirica* resulting good regeneration.

Regeneration of pine was good in stand P-I; in stand P-II where both seedlings and saplings were absent because of annual burning and trampling by the grazing cattle, its regeneration was poor. The keen competition offered to the pine seedlings by the overhead broad-leaved trees for light and by the dense undergrowth for water and nutrients appears to be the main reason for the absence of shade-intolerant pine saplings in stand P-III.

SUMMARY

The present study was conducted in three major forest types *viz.*, subtropical evergreen, subtropical semi-evergreen and subtropical pine forests of Meghalaya to study their distribution pattern, floristic composition, community structure, tree population structure and regeneration of dominant tree species. Their distribution pattern was studied using satellite Remote Sensing data and Geographical Information Systems, while community studies were carried out in two to three representative stands of each of the three forest types distributed in different parts of the state during March 2000 to February 2002.

As per the Report of Forest Survey of India (1999), total forest cover of the state is about 69.7% of the total geographical area. The subtropical evergreen forests account for 17.1%, subtropical semi-evergreen forests 30.7% and subtropical pine forests 10.9% of the total forested area of the state. Together they cover about 59% (*ca.* 41% of the total geographical area) of the total forest area of the state.

The climate of the state is strongly seasonal with 7-8 month-long rainy season and 4-5 months of relatively dry winter; summer is brief and mild. On account of wide variation in the annual rainfall from 1600 mm to 11,000 mm, a distinct climatic gradient from moist to perhumid condition exists in the state. The mean maximum temperature ranges between 15.1 ^{0}C and 31.7 ^{0}C and mean minimum temperature between 7.9 ^{0}C and 19 ^{0}C. The soils supporting

these forests are lateritic, acidic, low in TKN and available P and fairly high in SOM. The evergreen and semi-evergreen broad-leaved forests are found between 1000 m and 2000 m asl and the pine forests are distributed between 800 m and 2000 m asl. Since all three types of forests are distributed within the same altitudinal range, having similar rainfall and temperature regimes, their distribution at specific sites in different parts of the state appears to be related to the site conditions, particularly the soil moisture level and intensity of disturbance.

All the three forests are highly fragmented. About 60 to 90% of the forest patches are less than (≤) 10 sq. km area. Only 1 to 5% patches have an area of ≥ 100 sq. km. The pine forest is more fragmented than the broad-leaved forests.

In the broad-leaved forests, trees were distributed in three distinct strata namely, canopy (>20 m), sub-canopy (10-20 m) and treelet (2-10 m) layers. The average height of the canopy trees was greater in the semi-evergreen forest than the other two types. The pine forest had only two distinct strata, *i.e.* canopy and sub-canopy layers. The canopy in evergreen forest was composed of *Castanopsis tribuloides*, *Engelhardtia spicata*, *Dysoxylum gobara,* while *Vitex altissima*, *Schima wallichii*, *Echinocarpus murex*, *Dysoxylum binectariferum* and *Syzygium tetragonum* were conspicuous canopy trees in the semi-evergreen forest. In pine forest the canopy was made of either pure pine or pine mixed with some broad-leaved trees such as *Rhododendron arboreum* and *Schima wallichii.* There were 76-93 tree species (>15cm cbh) in the evergreen, 77-102 species in the semi-evergreen and 9-26 species in the pine forest. In the broad-leaved forests majority (79-88%) of the tree species was present in the sub-canopy and treelet strata, while in the pine forest the treelet layer (shrubs and tree saplings) had 77-81% of the woody species in the community. Lianas were absent in the pine forest.

The proportion of phanerophytes was 53 to 54% in the evergreen and semi-evergreen forests, which decreased to 33% in the pine forest, however, the proportion of therophytes was markedly higher (32%) in this forest compared to the other two forest types.

Whittaker's α-diversity (179-211) was highest in the subtropical semi-evergreen forest followed by evergreen (159-176) and pine (54-134) forests.

The tree species richness or species density per 100 m^2 was also high (3-27 species) in the semi-evergreen followed by evergreen (5-24 species) and pine forests, which had only 1-2 species. Species richness, species diversity and evenness indices were high in semi-evergreen and evergreen forests than the pine forest. Dominance index showed a reverse trend.

The evergreen and semi-evergreen forests were more heterogeneous and patchy in nature than the pine forest. *Saprosma ternatum*, *Syzygium cuminii* and *Aporusa oblonga* in evergreen, *Ficus racemosa*, *Daphniphyllum himalayense* and *Glochidion assamica* in semi-evergreen and *Pinus kesiya* in pine forests were the most frequent tree species.

Castanopsis kurzii, *Ficus elastica* (canopy species) and *Rhus javanica* (treelet layer) were dominant in the evergreen forests, *Dysoxylum* *binectariferum, Syzygium tetragonum* (canopy species) and *Aporusa oblonga* (sub-canopy layer) in the semi-evergreen forests and *Pinus kesiya* (canopy species), *Myrica esculenta*, and *Quercus glauca* (sub-canopy) were considered dominant in the pine forests on the basis of importance values. On the basis of family importance value Lauraceae, Rubiaceae and Euphorbiaceae were dominant in the subtropical evergreen and subtropical semi-evergreen forests. Pinaceae was the dominant family in the subtropical pine forest.

The tree stand density (stems per ha) was 834 - 1723 in the evergreen forest, 838 - 1063 in the semi-evergreen forests and 810 - 1050 in the pine forest. Their basal cover (m^2 ha^{-1}) ranged between 27 and 38.8, 25 and 49.5, and 28.9 and 37.4 in the evergreen, semi-evergreen and pine forests, respectively.

The dominance-distribution curves (log normal) of tree species showed high equitability and low dominance in evergreen and semi-evergreen forest communities and high dominance and low equitability (broken stick and geometric series model) in the pine forest.

The girth-class distribution pattern in the dominant species *viz.*, *Castanopsis indica*, *C. tribuloides*, *Callicarpa vestita* and *Symplocos spicata* in the evergreen forest, *Randia wallichii*, *Ficus racemosa*, *Helicia nilagirica*, and *Antidesma acidum* in the semi-evergreen forest and *Pinus kesiya* in stand P-I of the pine forest showed upright pyramidal population structure with large number of young (<15 cm cbh) individuals in their populations.

Pyramids of numbers of seedlings, saplings and adult trees in all the three-forest types were upright indicating good regeneration. However, a close examination of the population behaviour of the ten dominant tree species in each of the three forest types revealed wide variation in their regeneration behaviour. Regeneration was good in some species (*Castanopsis indica*, *Engelhardtia spicata, Helicia nilagirica* and *Callicarpa vestita*), poor in others (*Bridelia retusa, Persea duthiei* and *Rhododendron arboreum*), and in some species (*Ficus elastica* and *Saprosma ternatum*) no regeneration was observed. Poor regeneration could be due to several reasons, for example, the nature of species, non-availability of seeds, poor seedling establishment due to resource competition and alteration in regeneration niches due to disturbance.

Conclusions

All the three forest types are found inter-mixed at higher elevations of Meghalaya under similar climatic condition. However, the evergreen forest is found mainly at more humid and inaccessible least disturbed sites and, therefore, it is less fragmented. In this forest, the tree species richness and height of the canopy trees is lower than the semi-evergreen forest.

Though all the three forests fragmented, the pine forests found on nutrient-poor and relatively dry soil, are more fragmented and are poor in tree species richness than the other two types. In spite of the fragmentation and disturbance, regeneration of the dominant tree species in the evergreen and semi-evergreen forest is satisfactory. In pine forest regeneration of *Pinus kesiya* and *Schima wallichii* is better at warmer and moderately disturbed sites.

REFERENCES

Adler, F.R. and Nurenberger, B. 1994. Persistence in patchy irregular landscapes. *Theoretical Population Biology*, **45**: 41-75.

Aiba, S. and Kitayama, K. 1999. Structure, composition and species diversity in an altitude-substrate matrix of rain forest tree communities on Mount Kinabalu, Borneo. *Plant Ecology*, **140**: 139-157.

Allen, F.S., Grimshaw, H.M., Parkinson, J.A. and Quarmby, C. 1974. *Chemical Analysis of Ecological Materials.* Blackwell Scientific Publications, Oxford.

Anderson, J.M. and Ingram, J.S.P. 1993. *Soil Biology and Fertility* - A Handbook of Methods, 2nd edition. C.A.B. International, Wallingford, U.K.

Anon, 1974. Geology and mineral resources of the state of India. GSI, Miscellaneous Publication, **30**:124.

Anonymous 1984. *Meghalaya Forests.* Chief Conservator of Forest, Meghalaya, Shillong, India.

Archibold, O.W. 1995. *Ecology of World Vegetation.* Chapman and Hall, London.

Armesto, J.J., Mitchell, J.D. and Villagran, C. 1986. A comparison of spatial patterns of trees in some tropical and temperate forests. *Biotropica*, **18**: 1-11.

Arunachalam, A. 1996. *The role of litter and fine roots in organic matter and nutrient dynamics during the recovery of degraded subtropical forest ecosystems.* Ph.D. Thesis, North-Eastern Hill University, Shillong.

Ashton, P.S. 1969. Speciation among forest trees: some deductions in light of recent evidence. *Biological Journal of Linnanean Society*, **1**: 155-196.

Ashton, D.E. and William, E.J. 1982. Antagonisms in regeneration of *Eucalyptus regnans* in the mature forest. In: *The plant community as Working Mechanism* (Newmann, E.I., ed.), pp. 113-128. British Ecological Society.

Ashton, P.S. and Hall, P. 1992. Comparison of structure among mixed Dipterocarp forest of north-western Borneo. *Journal of Ecology*, **80**: 459-481.

Ashton, M.S. 1995. Seedling growth of co-occurring *Shorea* species in the simulated light environments of a rainforest. *Forest Ecology and Management*, **72**: 1-12.

Augspurger, C.K. 1984. Seedling survival among tropical tree species: Interaction of dispersal distance, light-gaps and pathogens. *Ecology*, **65**: 1705-1712.

Austin, M.P., Ashton, P.S. and Grieg-Smith, P. 1972. The application of quantitative methods to vegetation survey. III. A re-examination of rain forest data from Brunei. *Journal of Ecology*, **60**: 305-324.

Ayyappan, N. 2002. *Biodiversity of trees and short-term population changes in a tropical evergreen forest in the Anamalais, Western Ghats, India*. Ph.D. Thesis, Pandicherry University, Pandicherry.

Bailey, R.G. 1989. Eco-regions of the Continents. *Environmental Conservation,* **16:** 307-309.

Balakrishnan, N.P. 1981. *Flora of Jowai and Vicinity*. Vol. 1. Botanical Survey of India, Howrah.

Balakrishnan, N.P. 1983. *Flora of Jowai and Vicinity*. Vol. 2. Botanical Survey of India, Howrah.

Barik, S.K., Pandey H.N., Tripathi, R.S. and Rao, P. 1992. Micro-environmental variability and species diversity in treefall gaps in sub-tropical broad-leaved forest. *Vegetatio,* **103**: 31-40.

Barik, S.K., Tripathi, R.S., Pandey, H.N. and Rao, P. 1996. Tree regeneration in a subtropical humid forest: effect of cultural disturbance on seed production, dispersal and germination. *Journal of Applied Ecology,* **33**: 1551-1560.

Bhatt, D.M., Naik, M.B., Patagar, S.G., Hegde, G.T., Kanade, Y.G., Hegde, G.N., Shastri, C.M., Shetti, D.M. and Furtado, R.M. 2000. Forest dynamics in tropical rainforests of Uttara Kannada district in Western Ghats, India. *Current Science*, **79**: 975-985.

Bierregaard, R.O. Jr., Lovejoy, T., Kapos, V., daSantos, A. and Hutchings, R. 1992. The biological dynamics of tropical rain forest fragments. *Bioscience*, **42**: 859-866.

Bongers, F., Popma, J. del., Castilo, M. and Carbias, J. 1988. Structure and floristic composition of the lowland rainforest of the Los Tuxtlas, Mexico. *Vegetatio*, **74**: 55-80.

Browker, W.S. 1987. Unpleasant surprise in green house. *Nature*, **328**: 123-126.

Bunyavejchewin, S. 1999. Structure and dynamics in seasonal dry evergreen forest in northeastern Thailand. *Journal of Vegetation Science*, **10**: 787-792.

Brunig, E.F. 1983. Vegetation structure and growth. pp. 49-75. In: *Tropical Rain Forest Ecosystems: Structure and Function. Ecosystems of the World* (Golley , F.B., ed.) Volume 14A. Elsevier Scientific Publishing Co., New York.

Burkey, T.V. 1995. Tropical tree species diversity: a test of the Janzen-Connell model. *Oecologia*, **97**: 533-540.

Burton, P.J. and Mueller-Dombois, D. 1984. Response of *Metrosidros polymorpha* seedlings to experimental canopy opening. *Ecology*, **65**: 779-791.

Camargo, J.L. and Kapos, V. 1995. Complex edge effects on soil moisture and microclimate in central Amazonian forest. *Journal of Tropical Ecology,* **11:** 205-221.

Campbell, D.G., Daly, D.C., Prance, G.T. and Maciel, U.N. 1986. Quantitative ecological inventory of terrafirme and verzea forest on the Rio Xingu, Brazilian Amazon. *Brittonia*, **38:** 369-393.

Campbell, D.J., Stone, J.L. and Rosas, A.J. 1992. A comparison of the phytosociology and dynamics of three floodplains (varzea forest of known ages), Rio Jurua, Western Brazilian Amazon. *Bot. J. Linn. Soc.*, **108**, 213-237.

Cao, M. and Zhang, J. 1997. Tree species diversity of tropical forest vegetation in Xishuang banna, southwest China. *Biodiversity and Conservation*, **6**: 995-1006.

Champion, H.G. 1936. A preliminary survey of forest types of India and Burma. *Ind. For. Rec.,* **1**: 1-286.

Champion, H.G. and Seth, S.K. 1968. *A Revised Survey of the Forest Types of India.* Government of India Publication, Delhi.

Chauhan, A.S. and Singh, D.K. 1992. Changing pattern in the flora of Meghalaya due to deforestation. In: *Environment conservation and wasteland development in Meghalaya* (Gupta, A. and Dhar, D.C., eds.), Meghalaya Science Society, Shillong.

Chen, J., Franklin, J.F. and Spies, T.A. 1992. Vegetation responses to edges environments in old-growth Douglas-fir forests. *Ecol. Appl.*, **2:** 387-396.

Condit, R., Hubbel, S.P., LaFrankie, J.V., Sukumar, R., Manokaran, N., Foster, R.B. and Ashton, P.S. 1996. Species-area and species-individual relationships for tropical tree: a comparison of three 50 ha plots. *Journal of Ecology*, **84**: 549-562.

Condit,R., Ashton,P.S. Baker,P. Bunyvejchewin, S., Gunatilleke, S., Gunatilleke, N., Hubbel, S.P., Foster, R.B., Itoh, A., LaFranki, J.V., Lee, H.S., Losos, E., Manokoran, N., Sukumar, R. and Yamakura, T. 2000. Spatial patterns in the distribution of tropical tree species. *Science*, **288**: 1414-1418.

Colling, E.N.G. 1968. *Pinus merkusii.* Fast growing timber trees at the lowland tropics. Department of Forestry, Oxford.

Connel, J.H. 1971. On the role of natural enemies in preventing competitive exclusion in some marine animals and in rainforest trees. In: *Dynamics of populations* (Den Boer, P. and Gradwell, P.R., eds.), pp. 298-312.

Connell, J.H., Tracey, J.G. and Web, J.L. 1984. Compensatory recruitment, growth and mortality as factors maintaining rain forest tree diversity. *Ecological Monographs,* **54**: 141-164.

Connell, J.H. and Lowman, M.D. 1989. Low diversity tropical rainforest: some possible mechanisms for their existence. *American Naturalist*, **134**: 88-119.

Cox, C.B. and Moore, P.D. 1993. *Biogeography*: an ecological and evolutionary approach. Blackwell Scientific Publications, London.

Cross, J.R. 1981. The establishment of *Rhododendron ponticum* in the Killarney oakwoods, southwest Island. *Journal of Ecology,* **69**: 807-824.

Currie, D.J. 1991. Energy and large-scale patterns of animal- and plant- species richness. *American Naturalist*, **137**:27-49.

Dale, M.R.T. 1999. *Spatial Pattern Analysis in Plant Ecology.* Cambridge University Press, Cambridge.

Dallmeier, F. 1992. Long-term monitoring of biological diversity in tropical forest areas: Methods for establishment and inventory of permanent plots. *MAB Digest*, **11.** UNESCO, Paris, pp. 72.

Dinerstein, E. and Wikramanayake, E.D. 1993. Beyond "hotspots": How to prioritize investments in biodiversity in the Indo-Pacific region. *Conservation Biology,* **7**: 53-65.

Ehrlich, P. and Ehrlich, A., 1981. *Extinction: The Causes and Consequences of the Disappearance of Species*. Ballantine Books, New York.

Eiss, S. 1981. Effect of vegetative competition on regeneration of white spruce. *Canadian Journal of Forest Research*, **11**: 1-8.

Elton, C.S. 1958. *The Ecology of Invasions by Animals and Plants*. Methuen, London.

Eluoard, C. J. P., Pelissier, R., Ramesh, B. R., Hayllier, F., Durand, M., Anavajay, S., Moravie, M. A. and Carpentier, C. G. 1997. Monitoring the structure and dynamics of moist evergreen forest in the Western Ghats (Kodagh district, Karnataka, India). *Tropical Ecology*, **38**: 193-217.

Essen, Per-A. 1994. Tree mortality patterns experimental fragmentation of an old-growth conifer forest. *Biological Conservation,* **68**: 19-28.

Evans, J. 2001. *The Forest Handbook*. Vol. 1. Blackwell Science Ltd., USA.

Fahrig, L. and Merriam, G. 1994. Conservation of fragmented populations. *Conservation Biology*, **8**: 50-59.

Felfili, M. and Maria, J. 1995. Diversity, structure and dynamics of a gallery forest in Central Brazil. *Vegetatio,* **117**: 1-15.

FAO 1990. Forest Resource Assessment. Food and Agriculture Organization, Rome, Italy.

FAO 1995. Forest Resource Assessment. Publications Division, Food and Agriculture Organization, Rome, Italy

FAO 1997. Forest Resource Assessment. Publications Division, Food and Agriculture Organization, Rome, Italy.

Finol, U.N. 1971. Nuevos parametros a considerase en al analysis estructural de los selvas virgenes tropicales. *Rev. For. Venez.*, **21**: 29-42.

Flenley, J.R. 1979. *The Equatorial Rain Forest: a geographical history*. Butterworths, London.

Forest Conservation Act, 1980. *Rules and Guidelines*. Ministry of Environment and Forests, New Delhi.

Foster, D.R., Orwig, D.A. and Maclachalan, J.S. 1996. Ecological and conservation insights from re-constructive studies of temperate old growth forests. *Trends in Ecology and Evolution*, **11**: 419-424.

Frank, T.D. and Thorn, C.E. 1985. Stratifying alpine tundra for geomorphic studies using digitized aerial imagery. *Arctic and Alpine Research*, **17**: 179-188.

Frank, T.D. 1988. Mapping dominant vegetation communities in the Colorado rocky mountain front range with Landsat Thematic Mapper and Digital Terrain Data. *Photogrammetric Engineering and Remote Sensing*, 54: 1727-1734.

Franklin, S.B., Robertson, P.A., Fralish, J.H. and Kettler, S.M. 1993. Over-storey vegetation and successional trends of land between the lakes, USA. *Journal of Vegetation Science*, **4**: 509-520.

FSI, 1995. *The State of Forest Report*. FSI, Ministry of Environment and Forests, New Delhi.

FSI, 1997. *The State of Forest Report*. FSI, Ministry of Environment and Forests, New Delhi.

FSI, 1999. *The State of Forest Report*. FSI, Ministry of Environment and Forests, New Delhi.

Gadgil, M. and Meher-Homji, V.M. 1986. Localities of great significance to conservation of India's biological diversity. *Proc. Ind. Acd. Sci. Supp.* (Nov): 165-180.

Ganeshaiah, K.N., Shanker, R.V. and Bishwa, K.S. 1997. Diversity of species assemblages of Islands: Predictions and their test using tree species composition of Shola fragments. *Current Science*, **73**: 188-194.

Gentry, A.H. 1988. Changes in plant community diversity and floristic composition on environmental and geological gradients. *Ann. Missouri Bot. Gard.*, **75**: 1-34.

Gentry, A.H. 1990. Floristic similarities and differences between southern Central America and Upper and Central Amazonia. In: *Four Neotropical Rain Forest* (Gentry, A.H. ed.), pp.141-160. Yale University Press, New Haven.

Giles, P.T., Chapman, M.A. and Franklin, S.E. 1994. Incorporation of a digital elevation model derived from stereoscopic satellite imagery in automated terrain analysis. *Computers and Geosciences*, **20**: 441-460.

Givnish, T.J. 1995. Plant stems: biochemical adaptation for energy capture and influence on species distributions. Plant Stems: Physiology and Functional Morphology (Gartner, B.L., ed.), pp. 3-49. Academic Press, San Diego.

Grieg-Smith, P. 1983. *Quantitative Plant Ecology*, IIIrd eds. Blackwell, Oxford.

Haridasan, K. and Rao, R.R. 1985. *Forest Flora of Meghalaya*. 1st Vol., Bishen Singh Mahendrapal Singh, Dehra Dun, India.

Haridasan, K. and Rao, R.R. 1987. *Forest Flora of Meghalaya*. Vol. 2. Bishen Singh Mahendrapal Singh, Dehra Dun, India.

Harmer, R. 1995. Natural regeneration of broad-leaved trees in Britain. II Germination and Establishment. *Forestry*, **68**: 1-9.

Hart, T.B. 1990. Monospecific dominance in tropical rain forests. *Tre. Ecol. Evol.*, **5**: 6-11.

Harte, J., Kinzig, A. and Green, J. 1999. Self similarity in the distribution and abundance of species. *Science*, **284**: 334–336.

Herben, T., Ryden, H. and Soderstrom, L. 1991. Spore establishment probability and the persistence of the fugitive invading moss, *Orthodontium lineare*: a spatial simulation model. *Oikos*, **60**: 215-221.

Hobbs, R.J., Hussey, B.M.J. and Saunders, D.A. 1989. Nature conservation: the role of corridors. *IALE Bulletin*, 7 (2), December 1989.

Hooker, J.D. 1854. *Himalayan Journals*. 2 Vols. John Murray, London.

Horn, S.P. and Sanford, R.L. 1992. Holocene fires in Costa Rica. *Biotropica*, **254:** 354-361.

Hubbell, S.P. and Foster, R.B. 1983. Diversity of canopy tree in a neotropical forest and implications for conservation. In: *Tropical Rainforest: Ecology and Management* (Sutton, S.L., Whitmore, T.C. and Chadwick, A.C. eds.), pp. 25-41. Blackwell Scientific Publications, Oxford.

IUCN, 1991. *The Conservation Atlas of Tropical Forests: Asia and the Pacific.* Macmillan Press Ltd., London.

Jamir, A. 2000. *Studies on plant biodiversity, community structure and population behaviour of dominant tree species of some sacred groves of Jaintia hills, Meghalaya.* Ph.D. Thesis, North-Eastern Hill University, Shillong.

John, B. 1998. *Dynamics of fine roots in pine forest ecosystem*. Ph.D. Thesis, North-Eastern Hill University, Shillong.

Johns, R.J. 1993. Biodiversity and conservation of native flora of Papua New Guinea. In: *Papua New Guinea conservation needs assessment* (Beehler, B.M., ed.), pp. 15-75. Biodiversity Support Program, Washington, D.C.

Johnston, M. and Gillman, M. 1995. Tree population studies in low-diversity forest, Guyana. I. Floristic composition and stand structure. *Biodiversity and Conservation*, **4**: 339-463.

Joshi, N.V., Suresh, H.S. and Prabhakar, R. 1997. Hierarchial partitioning of tree diversity across spatial scales. A case study from the Nilgiri Biosphere Reserve, Southern India. *Int. J. Envir. Sci.*, **23**: 185-196.

Kadavul, K. and Parthasarathy, N. 1993. A quantitative inventory of plant biodiversity in the semievergreen forest of Shervaroy hills, Eastern Ghats. In: *Proceedings of annual session of Academy of plant sciences, India*. Seminar on biodiversity strategies for conservation and future challenges, Bharatihar University, Coimbatore.

Kadavul, K. and Parthasarathy, N. 1994. Biodiversity of trees and lianas and aspects of conservation in the forests of Kalyaran Kills, Eastern Ghats. Abstract. 17th all India. *Int. J. Env. Sci.*, **23**: 185 - 196.

Kadavul, K. and Parthasarathy, N. 1999. Structure and composition of woody species in tropical semi-evergreen forest of Kalrayan hills, Eastern Ghats, India. *Tropical Ecology*, **40**: 247-260.

Kanjilal, U.N., Kanjilal, P.C., Das, A. and Bor, N.L. 1934-1940. *Flora of Assam*. 5 Vols. Goverment Press, Shillong, India.

Kapos, V. 1989. Effects of isolation on the water status of forest patches in the Brazilian Amazon. *Journal of Tropical Ecology,* **5**: 173-185.

Kapos, V., Ganade, G., Matsui, E. and Victoria, R.L. 1995. $\delta^{13}C$ as an indicator of edge effects in tropical rain forest reserves. *Journal of Ecology*, **81**: 425-432.

Kareiva, P. 1987. Habittat fragmentation and the stability of predator-prey interactions. *Nature*, **326**: 388-390.

Kareiva, P. 1994. Space: the final frontier for ecological theory. *Ecology*, **95**: 1.

Kataki, S. K. 1983. Some rare plants in Khasi and Jaintia Hills of Meghalaya. In: A*n assessment of Threatened Plants of India.*(Jain, S.K. and Rao, R.R., eds), pp. 146-150. Botanical Survey of India, Howrah.

Keel, S., Genetry, H. and Spinzi, L. 1993. Using vegetation analysis to facilitate the selection of conservation sites in eastern Paraguay. *Conservation Biology*, **7**: 66-78.

Khan, M.L., Rai, J.P.N. and Tripathi, R.S. 1987. Population structure of some tree species in disturbed and protected sub-tropical forests of north-east India. *Acta Oecologia,* **8**: 247-255.

Khan, M.L. and Tripathi, R.S. 1991. Seedling survival and growth of early and late successional tree species as affected by insect herbivory and pathogen attack in subtropical forests of north-east India. *Acta Oecologia*, **12**: 569-579.

Khan, M. L., Menon, S. and Bawa, K.S. 1997. Effectiveness of the protected area network in biodiversity conservation: a case study of Meghalaya, India. *Biodiversity and Conservation*, **6**: 853 - 868.

Kilburn, P.D. 1966. Analysis of the species-area relation. *Ecology*, **47**: 831-843.

Kliejunas, J.T. and Ko, W.H. 1974. Deficiency of organic nutrients as a contributing factor to Ohia decline. *Phytopathology*, **64**: 891-896.

Knight, D.H. 1975. A phytosociological analysis of species-rich tropical forest at Barro Colorado Island, Panama. *Ecological Monograph,* **45**: 259-284.

Kowal, N.E. 1966. Shifting cultivation, fire and pine forests in the Cordillera Central Luzon, Philippines. *Ecological Monograph*, **36**: 389-419.

Krebs, C.J. 1989. *Ecological Methodology*. Harper and Row, New York.

Kumar, Y. 1984. *Studies on the flora of Balphakram Wildlife Sanctuary, Garo Hills, Meghalaya*. Ph.D. Thesis, North-Eastern Hill University, Shillong.

Kunin, W.E., Hartley, S. and Lennon, J.J. 2000. Scaling down: On the challenge of estimating abundance from occurrence patterns. *American Naturalist*, **156**: 560-566.

Lakshmi, U.V. and Dutta, C.B.S. 1996. Micro-level planning and sustainable forestry through GIS. *Current Science*, **75**: 245-255.

Lal, J.B.1989. *India's Forests: Myth and Reality*. Natraj publishers, New Delhi, India.

Lal, J.B., Gulati, A.K. and Bist, M.S. 1991. Satellite mapping of alpine pastures in the Himalayas. *International Journal of Remote Sensing*, **12**: 435-443.

Lamprecht, H. 1962. Ensayo sobre unos metodos para et analisis estructural de los bosques tropicales. *Acta. Cient. Venez.,* **13**: 57-67.

Laurance, W.F. 1991. Edge effects in tropical forest fragments: application of a model for the design of nature reserves. *Biological Conservation,* **57:** 205-219.

Laurance, W.F. and Bierregaard, R.O.Jr. 1997. *Tropical forest remnants: ecology, management and conservation of fragmented communities* (Laurance, W.F. and Bierregaard, R.O.Jr., eds). University of Chicago press, Chicago and London.

Laurance, W.F., Ferreira L.V., Rankin–de-Merona, J.M., and Hutchings, R.W. 1998. Influence of plot shape on estimates of trees diversity and community composition in central Amazonia. *Boitropica*, **30**: 662 – 665.

Lele, S. 1998. Meso-scale analysis of forest conditions and its determinants: a case study from the Western Ghats region, India. *Current Science*, **75**: 255-263.

Lewin, R. 1986. A mass extinction without asteroides. *Science*, **234**: 14-15.

Lieberman, D. and Lieberman, M., Peralta, R. and Hartshorn, G.S. 1996. Tropical forest structure and composition on a large-scale altitudinal gradient in Costa Rica. *Journal of Ecology,* **84**: 137-152.

Liu, D.S., Iverson, L.R. and Brown. S. 1992. Rates and patterns of deforestation in the Philippines: application of geographic information system analysis. *Forest Ecology and Management,* **57**: 1-16.

Loope, L.L. and Dunevitz, V.L. 1981. Impact of fire exclusion and invasion of *Schinus terbinthifolius* on limestone rockland pine forests of southeastern Florida. South Florida Research Center, Report T-645, pp. 30.

Maguire, A.D. and Forman, T.T.R., 1983. Herb cover effects on tree seedling patterns in a mature hemlock hardwood forest. *Ecology*, **64**: 1367-1380.

Magurran, A.E. 1988. *Ecological Diversity and its Measurement*. University Press, Cambridge.

Maithani, K., Arunachalam. A, Tripathi R.S. and Pandey, H.N. 1998. Influence of leaf litter quality on N-mineralization in soils of regrowing subtropical humid forest. *Biology and Fertility of Soils*, **27**: 44-50.

Majumdar, S.K. 1986. The pre-Cambrian framework of part of the Khasi hills, Meghalaya. GSI, **117**, pp. 59.

Mani, M.S. 1974. *Ecology and Biogeography in India*. pp. 159-177. W. Junk b.v. Publisher, The Hague.

Manokaran, N., La frankie, J. V., Kochumman, K. M., Quah, E. S., Klahn, J., Ashton, P. S. and Hubbell, S. P. 1991. Stand table and distribution of species in the 50 ha reserve plot at Pasoh forest reserve. Forest Research Institute of Malaysia, Reserve data.

Margalef, R. 1958. *Information Theory in Ecology. Gen. Syst.*, **3**: 36-71.

Matlack, G.R. 1994. Vegetation dynamics of the forest edge: trends in space and successional time. *Journal of Ecology*, **82**: 113-123.

May, R.M. 1975. Patterns of species abundance and diversity. In: *Ecology and Evolution of Communities* (Cody, M.L. and Dimond, J.M., eds.) pp. 340-379. Belknap press, Harvard University, Cambridge.

McCarthy, J. 1990. *Formalization of common sense : papers by John McCarthy,* edited by V. Lifschitz. *Ablex.*

McNaughton, S.J. and Wolf, L.L. 1970. Dominance and the niche in ecological systems. *Science*, **167**: 131-138.

Menon, S. and Bawa, K.S. 1997. Application of geographical information systems, remote sensing and landscape ecology approach to biodiversity conservation in the Western Ghats. *Current Science*, **73:** 134-145.

Mills, S.L. 1995. Edge effects and isolation: red-backed voles, on forest remnants. *Conservation Biology,* **9**: 395-403.

Millete, T.C., Talukdar, A.R., Kaperson, R.E. and Turner, B.L. 1995. The use and limits of remote sensing for analysing environmental and social change in the Himalayan middle mountains of Nepal. *Global Environmental Change-human and Policy Decisions*, **5**: 367-380.

Misra, R. 1968. *Ecology Work Book.* Oxford-IBH Publishing Company, Calcutta.

Mueller-Dombois, D. and Ellenberg, H. 1974. *Aims and Methods of Vegetation Ecology.* John Wiley and Sons, USA.

Mueller-Dombois, D., J.D. Jacobi, R.G. Cooray and N. Balakrishanan. 1980. Ohio rainforest study: Ecological investigations of the Ohio diebach in Hawaii. Hawaii Institute of Tropical Agriculrure and Human Resources, *Miscellaneous Publication* **183**. Honolulu, Hawaii, USA.

Mullin, R.E. and Browdery, L. 1977. Effects of seedbed, density and nursery fertilization on survival and growth of white spruce. *Forest Chronology*, **53**: 83-86.

Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. *Trends in Ecology and Evolution*, **10**: 58-62.

Murthy, M.N.V., Majumdar, S.K. and Bhaumic, N. 1976. Significance of tectonic trends in the geological evolution of the Meghalaya uplands; since the Pre-Cambrian. GSI, *Miscellaneous Publication*, No. **23**, pp. 471-484.

Myers, N. 1984. *The Primary Source: Tropical forest and our future.* W.W. Norton, New York.

Myrthong, S. 1980. *Studies on the Monocot Flora of Meghalaya.* Ph.D. Thesis, North-Eastern Hill University, Shillong.

Nadkarni, N.M., Matelson, T.J. and Haber, W.A. 1995. Structural characteristics and floristic composition of a neotropical cloud forest, Monteverde, Costa Rica. *Journal of Tropical Ecology,* **11:** 481-495.

Nayar, M.P. 1996. *Hotspots of endemic plants of India, Nepal and Bhutan.* Thiruvanthapuram.

Nicholson, S.A. and Monk, C.D. 1974. Plant species diversity in old field succession on the Georgia piedmont. *Ecology,* **55**: 1075-1085.

Noss, R.F. 1991. Landscape connectivity: different functions at different scale. In: *Landscape linkages and biodiversity* (Hudson, W.E. ed.), pp. 27-39. Island press, Washington, DC, USA.

Nunez-farfan, J. and Dirzo, R. 1998. Within – gap heterogenity and seedling performance in a Mexican tropical forest. *Oikos,* **51**: 274–284.

Ogawa, H., Yoda, K. and Kira, T. 1961. A preliminary survey on the vegetation of Thailand. *Nat. Life BE Asia (Kyoto),* **1**: 22-157.

Okuda, T., Naoki, K., Yap, S.K., Manokaran, N. 1997. Tree distribution pattern and fate of juveniles in a lowland tropical rain forest– implication for regeneration and maintenance of species diversity. *Plant Ecology*, **131**: 155-171.

Pandey, S.K. and Shukla, R.P. 2001. Population structure of woody plants in relation to disturbances including NTFP extraction in forests of north eastern Uttar Pradesh, India. In: *Tropical Ecosystems: Structure, diversity and human welfare* (Ganeshaiah *et al.* eds.), pp. 39-44.

Parthasarathy, N. and Karthikeyan, R. 1997. Population structure of *Grewia pandaica*, a rare and endemic tree species in south-west India. *I. J. Ecol.Env. Sci.*, **23**: 85-90.

Parthasarathy, N. and Sethi, P. 1997. Trees and liana species diversity and population structure in a tropical dry evergreen forest in south India. *Tropical Ecology*, **38**: 19-30.

Pascal, J.P. and Pelissier, R. 1996. Structure and floristic composition of tropical evergreen forest in southern India. *Journal of Tropical Ecology*, **12**: 195-218.

Pelissier, R. and Rierra, B. 1993. Dix ans de dynamique dune forest dense humide de Guyane Francaise. *Rev. Ecol.,* **48**: 21-33.

Peet, R.K. and Christensen, N.L. 1980. Succession: A Population Process. *Vegetatio,* **43**: 131-140.

Phillips, O.L. and Gentry, A.H. 1994. Increasing turnover through time in tropical forests. *Science*, **263**: 954 – 958.

Phillips, O.L. Hall, P., Gentry, A.H. Swayer, S.A. and Vazquez, R. 1994. Dynamics and species richness of tropical forests. *Proceedings of the National Academy of Sciences*, USA. **91**: 2805- 2809.

Pielou, E.C. 1975. *Ecological Diversity*. John Wiley and Sons, New York.

Prance, G.T., Rodrigues, W.A. and daSilva, M.F. 1976. Inventario florestal de um hectare de mata de terrafirme km 30 da estrada Manaus-Itacoatiara. *Acta. Amaz.*, **6**: 9-35.

Prance, G.T. 1979. Notes on the vegetation of Amazonia III, the terminology of Amazonian forests types subject to inundation. *Brittonia*, **31**: 26-38.

Puri, G.S. 1960. *Indian Forest Ecology*. Vol. 1. Oxford Book & Stationary co., New-Delhi and Calcutta.

Puri, G.S., Meher-Homji, V.M., Gupta, R.K. and Puri, S. 1983. *Forest Ecology*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Puri, G.S., Meher-Homji, V.M., Gupta, R.K., and Puri, S. 1989. *Forest Ecology*. 2 Vol. New Delhi, India: Oxford & IBH Publishing Company.

Rai, R.K. 1986. Evidences of Rejuvenation of the Deccan Foreland, India, with particular reference to the Meghalaya Plateau. In: *International Geomorphology* (Gardiner, V., ed.), pp. 255-266, Part II. John Wiley and Sons Ltd.

Rao, P., Barik, S.K., Pandey, H.N. and Tripathi, R.S. 1990. Community composition and tree population structure in a sub-tropical broad-leaved forest along a disturbance gradient. *Vegetatio*, **88**: 151-162.

Rao, P. 1992. *Ecology of gap phase regeneration in a subtropical broad-leaved climax forest of Meghalaya*. Ph. D. Thesis, North-Eastern Hill University, Shillong.

Rao, R.R. and Hajara, P.K. 1986. Floristic diversity of eastern Himalaya in a conservation perspective. *Proceedings Indian Academy of Sciences (Supplementary-* Nov), pp. 103-125.

Raunkiaer, C. 1934. *The life form of plants and statistical plant geography*. Being the collected papers of Raunkiaer, pp. 632. C. Oxford, Clarendon Press.

Ravan, S.A. and Roy, P.S., 1995. Landscape ecological analysis of a disturbance gradient using geographic information system in the Madhav National Park, Madhya Pradesh, *Current Science*, **68**: 309-315.

Read, J., Hallam, P. and Cherrier, J.F. 1995. The anomaly of monodominant tropical rainforests: some preliminary observations in the Nothophagus- dominated rain forests of New Caledonia. *Journal of Tropical Ecology,* **11**: 359-389.

Rice, E.E. 1974. *Allelopathy.* Academic press, New York.

Richards, P.W. 1996. *The Tropical Rain Forests.* 2nd edition. Cambridge University Press, Cambridge.

Ripple, W.J., Bradshaw, G.A. and Spies, T.A. 1991. Measuring forest landscape patterns in the Cascade Range of Oregon, USA. *Biological Conservation*, **57**:73-88.

Robinson, G.R., Holt, R.D., Gaines, M.S., Hamburg, S.P., Johnson, M.L., Fitch, H.S. and Martiniko, E.A. 1992. Diverse and contrasting effects of habitat fragmentation. *Science*, **257**: 524-526.

Rodgers, W.A. and Panwar, S.H. 1988. *Biogeographical Classification of India.* FRI, New Forest, Dehra Dun, India.

Rodriques, W.A. 1961. Estudo prelimnar de mata de varzea alta de uma ilha de baixo Rio Negro de solo agrilose e umide. *Ins. Nac. De Pessquisas da Amazonia,* Publication No.**10**, Manus, Brazil.

Roland, J. 1993. Large-scale forest fragmentation increases the duration of tent caterpillar outbreak. *Oecologia*, **93**: 25-30.

Roy, P.S. and Tomar, S. 2000. Biodiversity characterisation at landscape level using geospatial-modelling technique. *Biological Conservation,* **95**: 95-109.

Roy, P.S. and Tomar, S. 2001. Landscape cover dynamics in Meghalaya. *Indian Journal of Remote Sensing*, **22**: 3813-3825.

Roy, P.S., Dutt, C.B.S. and Joshi, P.K. 2002. Tropical forest resource assessment and monitoring. *Tropical Ecology*, **43**: 21-37.

Saunders, D.A., Hobbs, R.J. and Margules, C. 1991. Biological consequences of ecosystem fragmentation: a review. *Conservation Biology*, **5**: 18-32.

Saxena, A.K., Singh, S.P. and Singh, J.S. 1984. Population structure of forests of Kumaun Himalaya: Implications for management. *J. Env. Manag.,* **19**: 307-324.

Schulte, P.J. and Marshal, P.E. 1983. Growth and water relations of black locust and pine seedlings exposed to controlled water stress. *Canadian Journal of Forest Research,* **13**: 334-338.

Shannon, C.E. and Wiener, W. 1963. *The Mathematical Theory of Communication.* University of Illinois Press, Urbana.

Sharma, J.R. and Singh, D.K. 2000. Status of plant diversity in India. In: *Biodiversity and Environment* (Roy, P.S., Singh S. and Toxopeus, A.G. eds.). Indian Institute of Remote Sensing, Dehra Dun.

Simberloff, D.S. 1984. Mass extinction and the destruction of moist tropical forest. *Zh. Obshch. Biol*, **45**: 767-778.

Simpson, E.H. 1949. *Measurements of Diversity. Nature,* 163-688.

Singh, J. 1980. *Studies on structural and functional aspects of two sub- tropical humid forest types of Meghalaya.* Ph.D. Thesis, North-Eastern Hill University, Shillong.

Singh, S. 1996. *Technical report on delineation of geo-ecological zones in Meghalaya.* Report No. GE/UGC/SR (1)/SS. Department of Geography, North-Eastern Hill University, Shillong.

Skole, D. and Tucker, C.J. 1994. Tropical deforestation and habitat fragmentation in the Amazon: satellite data from 1987 to 1988. *Science*, **260**: 1905-1910.

Smith, N.H.J. 1981. Colonization lessons from a tropical forest. *Science*, **214**:755-761.

Sorensen, T. 1948. *A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Det. Kong. Danske Vidensk, Selsk Biology, Skr* (Copenhagen) **5**: 1-34.

Sorensen, F.C. and Ferrell, W.A. 1973. Photosynthesis and growth of Douglas-fir seedlings when grown in different environments. *Canadian Journal of Botany*, **51**: 1689-1698.

Srinivas, V. and Parthasarathy, N. 2000. Comparative analysis of tree diversity and disperson in tropical lowland evergreen forest of Agumbe, central Western Ghats, India. *Tropical Biodiversity*, **7**: 45-60.

Stainton, J.D.A. 1972. *Forests of Nepal.* John Murray Ltd., London, PP. 181.

Stewart, R.E. 1975. Allelopathic potential of western bracken. *Journal of Chemical Ecology*, **1**: 161-169.

Stout, I.J. and Marion, W.R. 1993. Pine flatwoods and xeric pine forests of the southern (lower) coastal plain. In: *Biodiversity of the southeastern United States, lowland terrestrial communities* (Martin, W.H., Stephen, B.G. and Arthur, E.C., eds), pp. 373-446. John Wiley and Sons, New York.

Strasberg, D. 1996. Diversity, size, composition and spatial aggregation among trees on 1 ha rainforest plot at La Reunion. *Biodiversity and Conservation*, **5**: 825-840.

Streng, D.R., Glitzenstein, J.S., and Harcombe, P.A. 1989. Woody seedling dynamics in an east Texas floodplain forest. *Ecological Monographs*, **59**: 177-204.

Sukumar, R., Dattaraja, H.S., Suresh, H.S., Radakrishnan, J.V., Vasudeva, R., Nirmala, S. and Joshi, N.V. 1992. Long-term monitoring of vegetation in a tropical deciduous forest in Mudumalai, southern India. *Current Science,* **62:** 608-616.

Swaine, M.D., Lieberman, D. and Putz, F.E. 1987. The dynamics of tree population in tropical forest: a review. *Journal of Tropical Ecology*, **3**: 359-366.

Tilman, D., May, R. M., Lehman, C. L. and Nowak, M. A. 1994. Habitat destruction and the extinction debt. *Nature*, **371**: 65-66.

Tiwari, B.K., Barik, S.K. and Tripathi, R.S. 1998. Biodiversity value, status and strategies for conservation of sacred groves of Meghalaya, India. *Ecosystem Health*, **4**: 20-32.

Tomar, S. 1998. *Vegetation type mapping and monitoring land-cover dynamics in Meghalaya (North-East Himalaya)*. Ph.D. Thesis, H.N.B. Garhwal University, Srinagar (Garhwal).

Tripathi, R.S. and Khan, M.L., 1992. Regeneration pattern and population structure of trees in sub-tropical forests of northeast India. In: *Tropical Ecosystems Ecology and Management* (Singh, K.P. and Singh, J.S. eds.), pp. 431-441. Wiley Eastern Limited, New Delhi.

Tripathi, R.S., Pandey, H.N. and Tiwari, B.K. 1996. State of Environment of Meghalaya. North-Eastern Hill University, Shillomg.

Turner, I.M. and Corlett, R.T. 1996. The conservation value of small, isolated fragments of lowland tropical rain forest. *Trends in Ecology and Evolution*, **11**:330-333.

Uma Shankar, 2001. A case study of high tree diversity in a sal (*Shorea robusta*)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Current Science*, **81**: 776-786.

Upadhaya, K., Pandey, H.N., Law, P.S. and Tripathi, R.S. 2002. Tree diversity in sacred groves of Jaintia Hills in Meghalaya, northeast India. *Biodiversity and Conservation*, **11**: 00.

Valencia, R., Balsley, H., Guillermo, P. Y. and Mino, C. 1994. High tree alpha diversity in Amazonian Ecuador. *Biodiversity and Conservation,* **3**: 21-28.

Vazquez, J.A. and Givnish, T.J. 1998. Altitudinal gradients in tropical forest composition, structure, and diversity in the Sierra de Manantlan. *Journal of Ecology*, **86**: 999-1020.

Vijaykumaran, N.P. and Menon, A.R.R., 1998. Estimation of bamboo resources in Kerala by Remote Sensing and GIS. *Current Science*, **70**: 209-210.

Virolainen, K.M., Suomi, T., Suhonen, J., and Kuitunen, M., 1998. Conservation of vascular plants in single large and several mires: Species richness, rarity and taxonomic diversity. *Journal of Applied Ecology*, **35**: 700-707.

Visalakshi, N. 1995. Vegetation analysis of two subtropical dry evergreen forests in southern India. *Tropical Ecology,* **36**: 117-127.

Walkey, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science*, **37**: 29-38.

WCMC 1992. *Global Biodiversity Strategy.* (Groombridge, B., ed.). World Conservation and Monitoring Centre, Chapman and Hall, London.

Webb, C.J., Tracey, J.G., Williams, W.T. and Lance, G.N. 1967. Studies in the numerical analysis of complex rain forest communities. I. A comparison of the methods applicable to site-specific data. *Journal of Ecology*, **55:** 171-191.

Webb, C.J., Tracey, J.G., and Williams, W.T. 1972. Regeneration and pattern in the subtropical rain forest. *Journal of Ecology*, **60**: 675-695.

Welden, C.W., Steven, W.H., Stephen, P.H. and Robin, B.F. 1991. Sapling survival, growth and recruitment; relationship to canopy height in a neotropical forest. *Ecology*, **72**: 35-50.

White, P.S. and Pickett, S.T.A. 1985. Natural disturbance and patch dynamics: an introduction. In: *The ecology of natural disturbance and patch dynamics* (Pickett, S.T. A. and White P.S., eds.) pp. 3-13. Academic press, Florida.

Whitford, P.B. 1948. Distribution of woodland plants in relation to succession and clonal growth. *Ecology,* **30**: 199-208.

Whitmore, T.C. 1975. *Tropical Rain Forests of Far East.* Oxford Clarendon Press.

Whitmore, T.C. 1984. Gaps in forest canopy. In: *Tropical Trees As Living Systems* (P.B. Tomlinson and M.H. Zimmermann, eds.), pp. 639-655. Cambridge University press, Cambridge.

Whittaker, R. H. 1960. Vegetation of the Siskiyou mountains. Oregon and California. *Ecological Monographs,* **30:** 279-338.

Whittaker, R. H. 1975. *Communities and Ecosystems.* Mac Millan Publishing Co. Inc. New York.

Williams-Linera, G. 1990. Vegetation structure and environmental conditions of forest edges in Panama. *Journal of Ecology,* **78**: 356-373.

Willis, E.J. 1980. *Allelopathy and its Role in forest of Eucalyptus regans* F. Muel. Ph. D. Thesis, University of Melbourne.

Wilson, E.O. 1988. *Biodiversity.* National Academy Press, Washington, DC.

Wright D.H. 1983. Species-energy theory: An extension of species-area theory. *Oikos*, **41**: 496-506.

APPENDIX (i)

Training Programmes attended:

(i) Three weeks training programme on Satellite data interpretation and its uses in forestry and ecology at Indian Institute of Remote Sensing, Dehra Dun.

(ii) Two months training Programme on National Natural Resource Management System (NNRMS) at Indian Institute of Remote Sensing, Dehra Dun.

Publications arising from the thesis:

Papers published/accepted:

Tripathi, O.P., Pandey, H.N. and Tripathi, R.S. 2001. Status of plant biodiversity in Mawlong Syiem sacred grove of Meghalaya, northeast India. In: *Perspectives of Plant Biodiversity*, (A.P. Das, ed.), Bishen Singh Mahendrapal Singh, Dehra Dun, PP. 663-680.

Porwal, M.C., Talukdar, G., Singh, H., **Tripathi**, **O.P.**, Tripathi, R.S. and Roy, P.S. 2000. Biodiversity characterization at landscape level using remote sensing and geo-spatial modeling in Meghalaya (India). In: *Biodiversity and Environment* (Roy, P.S., Singh, S. and Toxopeus, A.G., Eds.), PP. 206-219. Indian Institute of Remote Sensing (NRSA), Dehra Dun.

Pandey, H.N., **Tripathi**, **O.P.** and Tripathi, R.S. 2002. Ecological analysis of forest vegetation of Meghalaya. In: *Perspectives of Resource News*, (Bhatt *et al.*, eds.), ICAR, Barapani, Meghalaya. (*in Press*).

Papers communicated:

Tripathi, **O.P.**, Pandey, H.N, and Tripathi, R.S. 2002. Plant diversity and regeneration of pine (*Pinus kesiya* Royle ex Gordon.) in the subtropical pine forests of Meghalaya in northeast India. (Submitted: *Current Science*).

Tripathi, O.P., Pandey, H.N. and Tripathi, R.S. 2001. Fragmentation and biodiversity status of major forest types of Meghalaya, northeast India. (Submitted: *The Indian Forester).*